1421 Issued April 9, 1912.

HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

# ANNUAL REPORT

OF THE

# HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

# 1911.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

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## HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

### STATION STAFF.

E. V. WILCOX, *Special Agent in Charge.*
J. EDGAR HIGGINS, *Horticulturist.*
W. P. KELLEY, *Chemist.*
C. K. MCCLELLAND, *Agronomist.*
D. T. FULLAWAY, *Entomologist.*
W. T. MCGEORGE, *Assistant Chemist.*
ALICE R. THOMPSON, *Assistant Chemist.*
C. J. HUNN, *Assistant Horticulturist.*
V. S. HOLT, *Assistant in Horticulture.*
C. A. SAHR, *Assistant in Agronomy.*
F. A. CLOWES, *Superintendent of Hawaii Substations.*
J. DE C. JERVES, *Superintendent of Homestead Substation.*

# LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
*Honolulu, Hawaii, October 2, 1911.*

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year ended June 30, 1911.

Respectfully,

E. V. WILCOX,
*Special Agent in Charge.*

DR. A. C. TRUE,
*Director Office of Experiment Stations,*
*U. S. Department of Agriculture, Washington, D. C.*

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
*Secretary of Agriculture.*

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# ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1911

## SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

### BUILDINGS AND GROUNDS.

The new office building erected the previous fiscal year has served well the purpose for which it was erected, and is now used exclusively for the library, general office, and office of the entomologist. The quarters of the agronomist are in one portion of the old office building, which has been completely remodeled to accommodate the work of the departments of chemistry and agronomy. During the fiscal year ended June 30, 1911, a ginhouse was built for the better handling of the experimental cotton crops. In the center of the building the roller gin and gasoline engine are placed on cement bases, while around the sides of the building are arranged bins for holding seed and lint and for curing the seed cotton before ginning. Among the needs of the station for new buildings there is none greater than that of a glass propagating house in which the various seedlings can be properly protected from rain, wind, insects, and birds, and in which temperature conditions can be controlled, particularly to furnish bottom heat for certain seeds which require such heat in order to germinate properly. It is hoped that sufficient money may be obtained from Territorial funds during the next fiscal year to construct such a propagation house.

When the ground upon which most of the buildings of this station stand was formally turned over to the Department of Agriculture by the Navy Department a 2-acre plat located on Magazine Hill, near the front wall of Punchbowl, was also included. This ground has been cleared and planted to corn, cotton, and broom corn. The plat is in a very dry locality, most of the trade wind rains failing to reach it. Moreover, the soil is rather sandy and porous. An experiment has been carried on this year to determine how successfully corn, broom corn, and cotton will grow under such dry conditions. The best success was obtained with corn, particularly with the Yellow Creole variety.

On the slopes of Tantalus, at an elevation of about 750 feet, another small area which has previously not been cultivated was cleared and planted in Caravonica cotton, in order to compare the growth of this variety at the higher and the lower altitudes.

## CHANGES IN STATION STAFF.

During the year a few changes occurred in the staff of the station. Mr. F. G. Krauss resigned and his place was filled by the appointment of Mr. C. K. McClelland. Miss Alice R. Thompson being on a furlough for a year, it became necessary to appoint another assistant chemist. This position has been filled by the appointment of Mr. W. T. McGeorge. Mr. W. P. Kelley, the chemist, has planned for a furlough during the coming fiscal year, and therefore the chemical department will have but two members of the force during the year.

## DEMONSTRATION FARMS.

At the recent session of the Territorial legislature an appropriation of $20,000 was made for this station for the biennial period. It is understood that this sum of $10,000 per year is to be used chiefly in the establishment and maintenance of demonstration farms. Three such farms have already been located and are in operation. On the windward side of Hawaii two demonstration farms have been located, one at Hilo and one at Glenwood. At Hilo the area at the disposal of the station is about 2 acres, while the farm at Glenwood occupies 15 acres. The small plat at Hilo is taken up at present with experiments on bananas and taro. The renewed interest which has been shown in bananas has made it desirable to get some reliable data on the proper planting distance for Bluefields bananas and on fertilizers and cultural methods for this crop under the climatic conditions at Hilo. There was formerly a somewhat extensive banana industry in Hilo, and it is hoped that this may be revived with proper encouragement.

The problems to be studied at Glenwood are peculiar to that locality, but any results which may be obtained by careful experiments there will apply to a large area of possible homestead land. Many attempts have been made in the past to raise various crops such as are used in diversified agriculture and also sugar cane on the peculiar soils of this region, but without satisfactory results. The rainfall is very high, the soils being saturated most of the time. Moreover, the underlying strata of the soil are apparently of entirely different nature from the upper 3 or 4 inches, and while easily tilled and apparently porous are nevertheless difficult of aeration. The usual experience of attempting to raise crops on this soil has been that while the first crop was satisfactory in quantity a decided falling

off in the yield occurred in the second year and was more pronounced in any subsequent attempts at cultivation. It is necessary to determine what can be done in aerating this soil by different systems of plowing, including blasting with dynamite, fallowing, and burning the surface by means of log fires. Such burning of the soil in a few other localities in the Territory has given striking results in improving the physical structure of the soil and increasing the yields obtained. There is an encouraging local interest in solving these problems, and to this end $1,000 per year for a period of at least five years has been subscribed by private individuals and companies to supplement the Territorial funds in carrying on the experiments.

## COOPERATIVE EXPERIMENTS.

During the year a number of cooperative experiments have been carried on by arrangements with private individuals and companies. These experiments have included attempts to determine whether pineapples may be improved in form by selection of suckers from plants which bear fruit of the most desirable form; also fertilizer experiments with taro and rice, methods of propagating and the cultural requirements of the yellow sweet potato of the mainland, and pruning experiments with cotton. It is still too early to feel sure of the results from the selection work with pineapples. In the cooperative fertilizer experiment with taro it is obvious that this plant, like rice, is benefited by allowing the soil to dry out and become aerated between crops, by applying all of the fertilizer before planting rather than after planting or in fractional doses, and by using sulphate of ammonia rather than nitrate of soda as a source of nitrogen. It has been found that the yellow sweet potato, known under various names on the mainland, may be made to yield a good quality of tubers in various localities in the Territory and that these tubers bring a high price (up to 8 cents per pound) when shipped to California during the season when mainland sweet potatoes are not to be had. The pruning experiments with cotton are only well under way. They are designed to test out on a large scale the results which have already been obtained on smaller areas upon the station grounds.

## ENTOMOLOGICAL INVESTIGATIONS.

During the year the most important entomological occurrence in Hawaii was the discovery of the Mediterranean fruit fly. It is not certain when this pest first found its way into Hawaii, but, at any rate, the presence of the insect was not definitely known until this year. After its discovery it spread with remarkable rapidity, attacking peaches, all of the citrus fruits, mangoes, peppers, guavas, figs, and

avocados. The occurrence of this pest in Hawaii led to the prompt establishment of a quarantine on the part of California against Hawaiian fruits, except pineapples and bananas. The last two fruits are the only ones which were already being shipped in large quantities to the mainland, but there is an increasing demand in California and elsewhere for avocados, mangoes, and also papayas. The outlet for these fruits is therefore completely closed for the present until some effective method of control can be devised. This station has taken part in devising such a plan. The essential features of the plan at present consist in the careful daily collection of all fallen fruit and the removal of such fruit by the official garbage collectors, followed by burning, or collection by hog raisers, who boil the fruit before feeding. The results of this campaign are already evident and it seems possible gradually to reduce the numbers of the fly by this same means if the proper cooperation of householders and all interested parties can be maintained.

The growing importance of corn and leguminous crops in the problem of securing more forage has led to the cultivation of greatly increased areas of these crops and has also directed attention to some of their insect pests. The entomologist gave particular attention during the year to the insect pests of legumes and corn. The most important pests of legumes are considered in this report, and those of corn are to be treated in a forthcoming bulletin of the station. In these investigations it has been found that in some localities plant lice are very effectively parasitized. By artificially distributing these parasites about 95 per cent of the plant lice were attacked and destroyed. It is hoped that these parasites will become of great value in checking the annual losses from plant lice. Some attention has been given to the possible control of the cotton bollworm by means of parasites. A parasite is already known in Hawaii which destroys from 5 to 10 per cent of the bollworms, but a more effective one must be secured if possible. The Cotton Growers' Association, recently organized, proposes to raise sufficient funds to obtain additional parasites from India and other places where this pest is native.

## HORTICULTURAL INVESTIGATIONS.

One of the chief lines of study during the year was concerned with the avocado. A budding method has been perfected by means of which success is obtained on young trees in from 85 to 90 per cent of cases and on old trees, by the method of top-working, in from 50 to 75 per cent of cases. Moreover, a successful inarching method has been devised for rapidly testing out promising seedlings. A collection has been made, as complete as possible, of the types of avocados found in Hawaii and a system of classification and description is now

being worked out. This fruit shows a great variety of forms, not only of shape, color, and flavor, but also in the relative proportion of pulp to seed and in the thickness of the rind.

The variation in the flavor, size, and shape of papaya fruits is almost unlimited. A part of this variation seems to be due to the crossings which have taken place between the different varieties or perhaps between species. The only practical method of propagating papayas is by means of seed. Obviously, therefore, in order to eliminate variation and establish varieties which will come true it is necessary in some manner to prevent too much crossing. In the work done on papayas at this station it has been found possible to propagate the fruit by the use of monœcious trees without the help of sterile male trees. If it should prove a practical matter to secure the desired flavor and other qualities by this method alone, it will thereby become possible to avoid the loss of space incident to the growing of a large number of male trees and the lack of uniformity which has hitherto occurred when dependence was placed on the fertilization of the pistils of one form of dicœcious trees with the pollen of another form.

During the year the station has had an unusual number of requests for budwood of various fruit trees and for seedlings of these and various ornamentals. The requests of this sort from the War and Navy Departments have been the largest, and so far as possible the station has cooperated in furnishing material to improve the grounds of the newly established Army posts and naval stations. The larger part of the distribution of such material made by the station is directly along the lines of work now being carried on. An attempt is being made to reduce so far as possible the distribution of miscellaneous sorts in order that this may not interfere with the time of the members of the staff. Attention has previously been called to the fact that some of this work of distributing ornamentals and miscellaneous fruits and vegetables should be taken up on a commercial scale by some nurseryman.

## CHEMICAL INVESTIGATIONS.

The investigation of manganese soils has been continued during the year. The results obtained in this work have added greatly to the knowledge of conditions which prevail in these soils and have helped to shape a practical policy of utilizing these soils, particularly in the pineapple districts. It may now be confidently asserted that highly manganiferous soils should be avoided in planting pineapples. This fruit is exceptionally sensitive to unfavorable soil conditions and can not be made to thrive on soils which contain from 4 to 5 per cent of manganese. A number of other crops are less sensitive to manganese and thrive fairly well on such soils. Among these may be mentioned

sugar cane, corn, and cotton. If for any reason it is especially desired to grow pineapples on highly manganiferous soils, the best results can be obtained by planting the old stumps rather than the suckers and by fertilizing heavily with phosphates.

It appears more and more certain that pineapples do not require so much water as has sometimes been supposed; in fact, one of the most serious difficulties in the pineapple district of Wahiawa, where about 5,000 acres of pineapples are grown, is in securing the proper drainage of the soils. It has been necessary to plow the land in such a way as to obtain ditches with the proper grade to carry off the excess of water. Tiles for drainage are too expensive in Hawaii and they can not be thought of as a practical treatment of the drainage problem at present. It is of great importance that the cultivation of pineapple soils should be avoided when these soils are too wet, otherwise they will become so badly puddled as to make proper drainage impossible. There are locations, particularly on Maui and Kauai, where the soils are not so easily puddled and where drainage is naturally accomplished in a satisfactory way, even in the presence of a larger rainfall than occurs in the Wahiawa section. On properly tilled soils the experiments thus far carried on with fertilizers show that the best combination for pineapples is superphosphate, sulphate of potash, and ammonium sulphate.

The fertilizer experiments with rice have been continued on the same plats and along the same line as was reported last year. The results secured on the two crops during the year were strictly in harmony with those previously obtained. It is evident that all the fertilizer should be applied to rice before planting and that nitrogen should be supplied in the organic form or in the form of ammonia rather than as nitrate.

In the fertilizer experiments with cotton a large increase in yield was brought about by a proper combination of different elements of plant food. The results as a whole, however, show that on the soils thus far used for growing cotton, phosphoric acid is the element which is most needed and the one which produces the most striking increase in yield.

Data are gradually being accumulated for a general classification of Hawaiian soils. It is impossible to classify them according to the schemes ordinarily adopted on the mainland, for the reason that physical and chemical properties of Hawaiian soils are so peculiar that the soils do not readily fall into mainland categories of classification. Among some of the more strikingly peculiar soils it is only necessary to mention those which contain from 8 to 10 per cent of manganese and an area which was recently found to contain 20 per cent of titanium.

The work in prospect for the coming year includes a study of sisal waste, the determination of the amount of oil in the kukui nut and practical methods for extracting it, a study of pineapple stumps with reference to their possible use in starch manufacture, a study of the prevalence of chlorin and sulphur in plants, and tests of the effect of heat on soils which show poor drainage.

## COTTON.

Interest in cotton in Hawaii continues to increase, and the results thus far obtained justify the much larger plantings which have already been made. It was necessary in the first place to carry on much experimental work to determine under what conditions cotton would thrive best and the cultural methods which must be adopted to insure success. All cotton plantings in the Territory at low elevations or in localities protected against the trade wind have shown large yields of lint of good quality. The returns coming in from the early crop show yields of from 400 to 600 pounds of lint per acre, and also indicate that a practical method of holding the bollworm injury within bounds is now in operation.

One of the unsuspected results obtained in the cotton experiments of the station is the proof of the peculiar sensitiveness of cotton to even moderately cool weather. At low altitudes the temperature rarely falls as low as 60° F. At such a temperature, however, if accompanied by moderate trade winds, the leaves of cotton may be browned and curled as if frostbitten. While the trade winds are never strong as compared with the high winds which occasionally prevail on the mainland, yet their constant blowing from one direction largely prevents the setting of the bolls on the outside row of cotton toward the northeast. In isolated plants the windward side may be without bolls while the leeward side of the same plant is heavily loaded. The beneficial effect of windbreaks is very pronounced in all cotton fields exposed directly to the trade winds. In protected localities, however, the growth, yield, and quality are all that can be desired.

A number of plantings have been made in coral sand at sea level, even on the windward side of the islands, and in all of these plantings the cotton has grown and borne well. It appears that no injury is produced even if the roots reach down into the salt water. Heavily bearing plants may be seen in sand not over 2 feet above sea level and within 10 feet of the water's edge. In Hawaii, as elsewhere, it is evident that cotton can not obtain too much sun nor too much heat, but that too much rain may be injurious.

Success with cotton in Hawaii is not determined by altitude alone, for excellent fields are to be seen at altitudes of from 700 to 1,600 feet. These, however, are located in sections where the trade wind is broken by mountains. It is impossible to give with certainty the

rainfall which cotton will endure, but in soils retentive of moisture a good crop has been made with 15 inches of rain, and the other limit of variation would seem to be about 80 inches. With too much rainfall all the varieties of cotton with which the station has experimented grow too tall, thus making picking difficult and increasing the cost of harvesting.

The practical control of the bollworm may be accomplished by pruning back the whole field at the close of each picking season and burning all the rubbish promptly. The larvæ and pupæ of the bollworm are found in the infested bolls and are destroyed by burning. Pruning interrupts the crop of bolls as completely as a new planting where the cotton is treated as an annual. It is necessary to prune not only to keep down damage from bollworms but also to hold the plants in proper form; otherwise cotton grown as a perennial attains a size and shape which renders picking difficult. By proper pruning and pinching the terminal buds, it has been found possible to increase greatly the number of lateral branches and to hold the plants within a proper size. Growth from pruned plants is considerably more rapid than from seed, and the yield of such plants is larger than from seedlings the first year. It is barely possible, therefore, that in the extreme southern portion of the cotton belt of the South the same method might be used, provided that the pruning is done low and the stumps protected from the winter frosts by mulching. Upland cotton does not ratoon as promptly, however, as Caravonica and Sea Island.

The danger of hybridization if different cottons are grown in close proximity is apparently greater than has usually been stated. On the station grounds each variety was grown in an isolated spot, at least 300 yards from any other variety. In this way it was possible to make seed selections from year to year with reasonable assurance of success and purity of strain. A peculiar type of Caravonica cotton has developed in which the lint is unusually harsh and strong. This seems to be particularly well suited for mixing with woolen goods, and reports received on samples of the lint indicate that it will be readily bought for that purpose. The latest quotations on lint of cotton samples, which the station has submitted to buyers and cotton graders, are 40 cents for Sea Island, 28 cents for Sunflower, and 25 cents for Caravonica.

## MISCELLANEOUS.

The results from the introduction of Japanese rices have not been completely satisfactory. Samples of milled rice submitted to various individuals supposed to be judges of the milled product have brought various opinions which are not quite in harmony. A few have stated

that rice grown in Hawaii from seed imported from Japan is equal in every way to imported Japanese rice. Others have rated it as inferior to the imported rice or as differing from it in certain culinary or other properties which are hard to define, and on which the different individuals to whom the rice was submitted did not agree. The yield of the Japanese rices is satisfactory. There is a general depression in the rice industry in Hawaii, largely due to the preference of the Japanese for the rice imported directly from Japan, and to the further fact that only Chinese labor is available for work in the rice fields and that this labor is scarce and demands an increasing wage. These facts, combined with the high rentals (from $25 to $40 per acre annually) which the rice growers pay for their land, make it difficult to obtain a profit from growing rice.

As a result of experiments with broom corn it has been found that a good quality of brush can be produced in Hawaii, somewhat superior to that grown in California and nearly equal to that obtained in the Central States. A broom factory has been established which can use more brush than is now produced in Hawaii. A number of rice growers and others are beginning to plant this crop in order to supply the local demand. Little difficulty has been experienced in growing broom corn, except in the occasional attacks of plant lice.

There is an increasing demand for leguminous crops for a great variety of purposes. The sugar planters are looking for suitable legumes to grow between the rows of cane for controlling weeds and as a source of nitrogen. Dairymen and ranchers have use for all of the leguminous crops which they can produce for feeding green. The pineapple growers need a suitable legume as a rotation crop and orchardists as a cover crop. For dairy purposes alfalfa, jack beans, and cowpeas are perhaps the best legumes. In some of the pineapple districts pigeon peas have proved superior to all other legumes as a rotation crop. The station is testing all legumes which can be considered as suitable for Hawaii in various locations on the different islands, and the results of the experiments are quickly adopted by the planters and farmers.

Corn is not produced in sufficient quantities to supply the local demand. On one of the larger ranches about 1,400 acres of corn were grown this year, with an average yield of about 35 bushels per acre. All this corn, however, is used for feeding on the ranch. Smaller plantings are being made on other ranches with satisfactory results, but without adding any to the supply of corn on the market, since it is all used in feeding beef cattle and horses. A number of farmers have engaged in corn raising to supply corn for the horses and mules of neighboring plantations. The only serious difficulty in raising corn in Hawaii is of an entomological nature. A bulletin on corn

insects was prepared during the year. A variety of flint corn known as Yellow Creole and recommended as being resistant to corn insects in Louisiana is being tested out, with promising results.

During the year the following publications were issued by the station:

Bulletin No. 21. A Study of the Composition of the Rice Plant.
Bulletin No. 22. Insects Attacking the Sweet Potato in Hawaii.
Bulletin No. 23. Leguminous Crops for Hawaii.
Bulletin No. 24. The Assimilation of Nitrogen by Rice.
Bulletin No. 25. The Avocado in Hawaii.
Press Bulletin No. 27. Use of Insecticides in Hawaii.
Press Bulletin No. 28. Peanuts in Hawaii.
Press Bulletin No. 29. The Management of Pineapple Soils.
Press Bulletin No. 30. Killing Weeds with Arsenite of Soda.
Pamphlet on Taro, in Hawaiian.
Pamphlet on Bananas, in Hawaiian and Portuguese.
Pamphlet on Grapes, in Portuguese.
Pamphlet on the Grazing Industry, in English.

## REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

This report covers the periods from July 1 to August 15 and from January 1 to May 15. The entomologist was absent on leave from August 16 to December 31, and on May 16 was transferred to the experiment station at Guam. The routine work of the office, however, was adequately attended to throughout the year and the collections were maintained and much material added. Numerous inquiries regarding destructive insects and remedies therefor were answered by letter or given personal attention.

The investigation of the insects affecting cereal crops, begun the previous year, was continued, and a part of the results are to appear in a later bulletin of the station.

The growing interest in leguminous crops for fodder or soil improvement induced the entomologist to give some attention to the destructive insects of the commoner legumes. The following notes cover observations on the insects attacking the pigeon pea (*Cajanus indicus*), cowpea (*Vigna catjang*), jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna pruriens*), soy bean (*Glycine hispida*), peanut (*Arachis hypogœa*), sweet clover (*Melilotus officinalis*), and alfalfa (*Medicago sativa*). More attention was given to pigeon pea than to the other mentioned crops and, while the list is admittedly not complete for all of these plants, it indicates in a general way what the agriculturist has to contend with in the cultivation of legumes.

### NOTES ON INSECTS ATTACKING LEGUMINOUS CROPS.

Leguminous crops are subject to attacks of cutworms and army worms, especially in the winter and spring or on irrigated land. Large fields of alfalfa are sometimes devastated by the army worm, *Heliophila unipuncta*, before it can be brought under control by its natural enemies. Extensive plantings of jack beans have been laid waste by another common army worm, *Spodoptera mauritia* (fig. 1). Swezey records *Spodoptera exigua* from peas and beans, and the writer bred *Heliothis obsoleta* on pigeon pea. One enterprising farmer checked an attack of army worms by flooding his fields. The caterpillars, floating on the water or caught in the meshes of

stranded vegetation, were greedily devoured by mynah birds. Cutworms and army worms are usually kept in check by their parasites—the tachinid flies, *Frontina archippivora* and *Cheatogædia monticola*, the ichneumonid, *Ichneumon koebeli*, and birds. It is, however, sometimes advisable to protect fields from cutworms by spreading out, near the plants, poisoned bait, consisting of arsenic and bran, with a small amount of sugar or molasses to moisten the mixture.

The foliage of legumes is often badly eaten by certain leaf-rollers, *Omiodes monogona* (fig. 2), *Amorbia emigratella* (fig. 3) and *Archips postvittanus*, and by the looper, *Plusia chalcites*, but the damage they inflict is apparently not great except in the case of *Omiodes monogona*, which, so far as is known, feeds exclusively on legumes. It, however, is subject in turn to the attacks of parasites which keep it fairly well in check. *Limnerium blackburni* has been bred from it by Mr. Swezey, and the writer bred *Chalcis obscurata* from the pupæ.

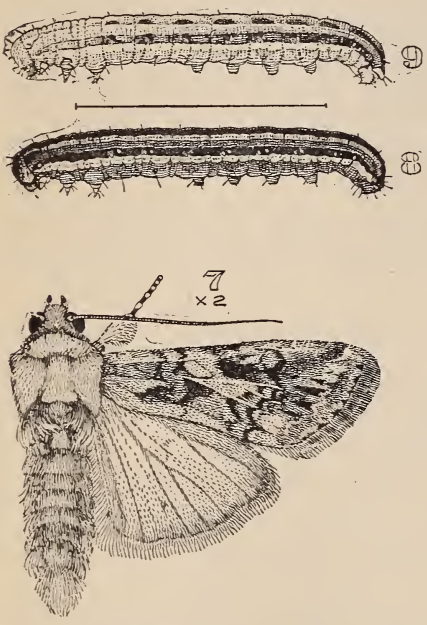



FIG. 1.—*Spodoptera mauritia:* Larva and adult.

Plant-lice or aphids are usually found on cultivated legumes and are likely to affect the growth seriously, especially in the winter months. Some legumes seem to suffer more than others, notably the cowpea, which sometimes becomes so badly infested that it is impossible to get a good stand. The species which attacks legumes is thought to be *Aphis gossypii*. When the infestation is bad, the dark form, ranging from dull purplish-black to shining piceous black, prevails. It is often necessary to spray legumes threatened with aphid injury with tobacco decoctions and nicotine solutions, which are fairly cheap and effective agents to use in such cases. Aphids are fairly well kept in check most of the time by ladybird or coccinellid beetles, of which there are numerous introduced species present. The larvæ of the syrphid fly, *Xanthogramma grandicornis*, and of the agromyzid, *Leucopis nigricornis*, also prey on aphids and are usually found where aphids are abundant.

The common representative of the scale insects (Coccidæ) found on legumes is the cottony cushion or fluted scale, *Icerya purchasi*, which, while normally controlled by *Novius cardinalis*, sometimes becomes very abundant and does considerable damage before the ladybirds become numerous enough to clean it out. Pigeon pea and

peanuts are usually more badly infested than other legumes. Cutting and destroying all badly infested branches as soon as noticed is recommended. When abundant the scale insects are usually massed together on the stems and very little work is involved in thus getting rid of them. Mealy bugs, embracing several species, infest legumes,

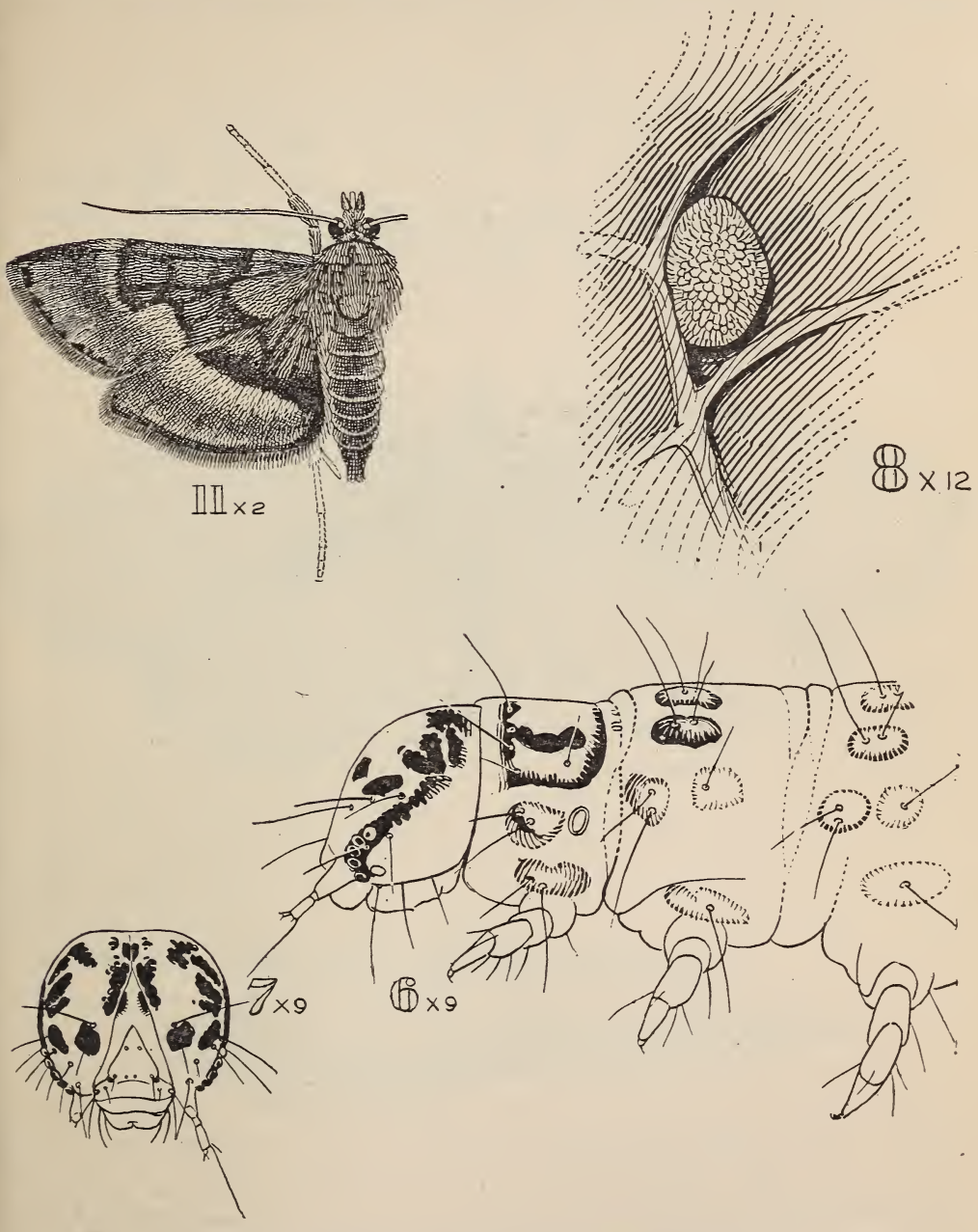



FIG. 2.—*Omiodes monogona:* Adult, egg, and larva.

notably *Pseudococcus longispinus*, *P. citri*, *P. virgatus*, and *P. fiamentosus*, but do little apparent damage and are usually controlled by their parasites and predators. The first three species have been noticed on pigeon pea and the last more especially on clover. The flat scale, *Saissetia oleæ*, is common on pigeon pea and crotalaria.

The leaves of most of the cultivated legumes and some other plants as well are mined by the larva of a small agromyzid fly, determined by the late D. W. Coquillett, of the Department of Agriculture at Washington, as *Agromyza diminuta.* The wandering track of the miner in the mesophyll is indicated by a rather broad line of transparent green which contrasts boldly with the darker shade of the leaf.

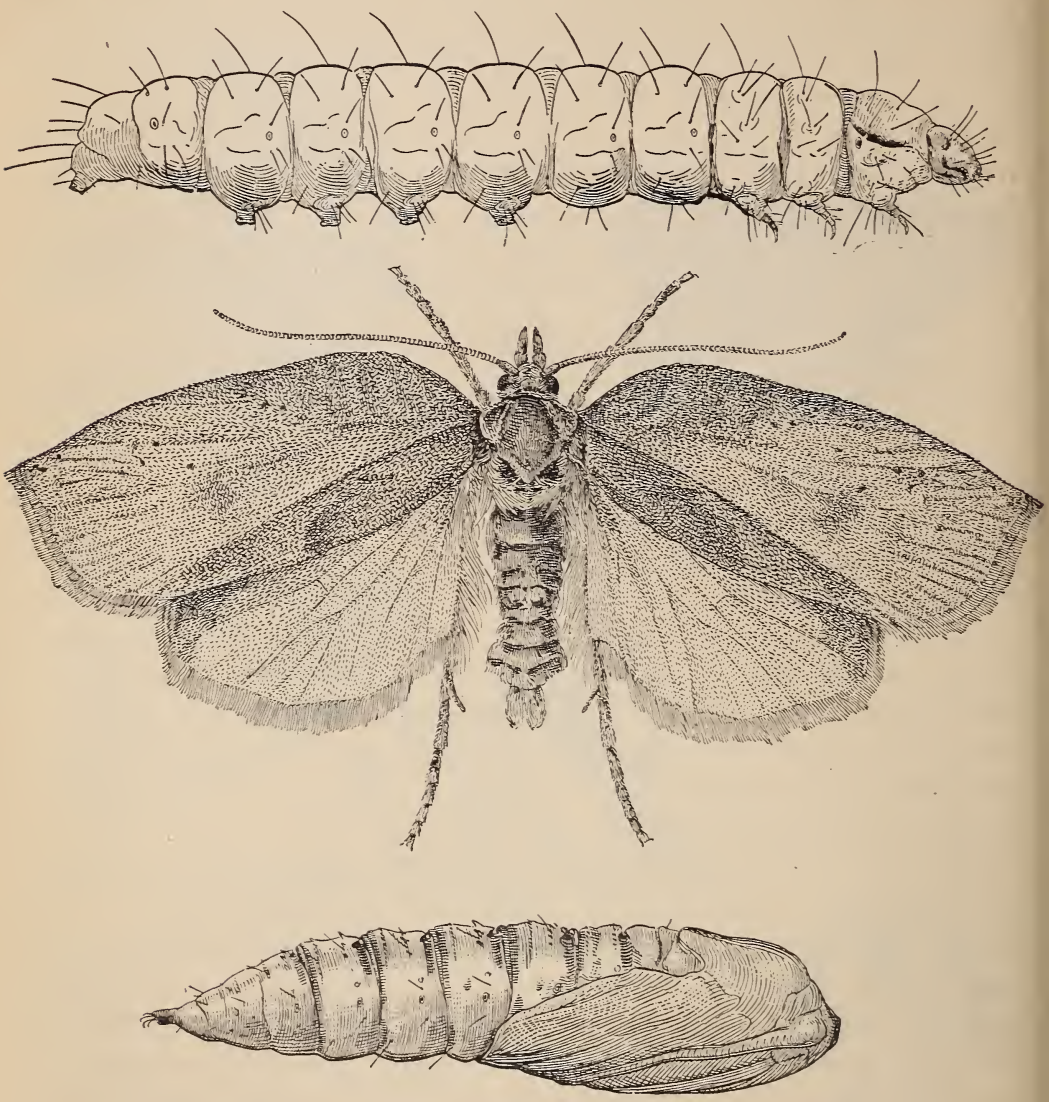


FIG. 3.—*Amorbia emigratella:* Larva, moth, and pupa.

The foliage is often badly shattered, and if the mining is extensive, one surface of the leaf will usually split when the leaves become dry and brittle. This miner, however, will probably never be a serious pest, as it is effectively parasitized by the eulophids, *Omphale metallicus* and *Pediobius* sp. The adult fly is the pretty little black and yellow two-winged insect often seen hovering about the foliage of legumes. It has been bred from leaves of cabbage, geranium, and

nasturtium as well as from the following legumes: Jack beans, cowpeas, alfalfa, and clover. The larva, when mature, leaves the leaf by breaking through the epidermis and enters the ground to pupate.

Probably the most injurious insect attacking legumes is the one designated the bean pod borer, the larva or caterpillar of the common blue or hairstreak butterfly *Lycæna bætica*. This is a widely distributed pest, not, however, found in America. Its habitat as given by Meyrick is western France (an occasional emigrant to England), southern Europe, central and southern Asia, Africa, Australia, and the Pacific Islands. It attacks the pods of various legumes, devouring the growing seeds. The pigeon pea, according to my observation, is more severely attacked than other legumes, but the crotalarias and garden peas and beans are usually infested. I have also found the eggs on jack beans and cowpeas. The following is an account of its life history:

The eggs are laid singly, on the outer parts of the flower (sepals and bracts), on the leaves, and on the stems. They are pale green when fresh, depressed spheroidal, 0.5 millimeter in diameter, 0.27 millimeter high; openly reticulate, the network formed by well-developed ridges; tuberculate at the angles of intersection. The reticulation is more closely drawn around the micropyle, which lies in a shallow depression. The base is rather flat and rather faintly sculptured.

The larva emerges through a hole made in the top and at the time of hatching is about 1 millimeter long, body yellowish green, head black, cervical shield conspicuous, transversely rhomboidal, fuscous, anal shield black, more or less cylindrical, tubercles black, minute, each with a seta, arranged in longitudinal rows, 1 close to dorsal line and more or less posterior in the segment, 2 a little more removed and anterior, larger than 1, 3 above the spiracle, 4 and 5 below, 4 anterior, 5 posterior in the segment, 6 and 7 beneath, hairs longer laterally and caudally. The larva moults three times during the course of its growth. When full grown it is about 14 millimeters long, 4.5 millimeters wide, onisciform in shape, the segmentation distinct. The head is small, about 1 millimeter wide, retractile and usually hidden beneath the first segment, rounder in front, slightly depressed, testaceous, lower margin of ocelli broadly, upper margin narrowly, labrum, anterior margin of interlobular area and borders of lobes entirely black. The body is plump, light green, with the following claret markings, the colors varying greatly in intensity; dorsal line, beginning at anterior margin of third segment and extending to tip, a deep claret, oblique claret suffusion on each segment, midway between dorsal line and spiracles, pale claret suffusion laterally along spiracular line. Thickly covered with irregular blackish and whitish tubercles bearing short brownish hairs; more

closely crowded on eleventh and twelfth segments. Legs brownish with black tips; spines on prolegs claret colored, lateral line and under side of body very pale green. Three last segments depressed, linguiform. Hairs longer on first and second segments and under side of body. The length of the larval stage is about 18 days.

The pupa is about 10 mm. long and of the usual lycænid form. Outline from above irregularly oval, greatest width 4.5 mm., at fourth abdominal segment. Dorsum rounded, venter more or less flat, thorax gibbous, a large well-formed gibbosity dorsally and smaller protuberance laterally. Cephalic margin truncate, slight constriction at first abdominal segment, body gradually contracting beyond fourth segment. Luteo-testaceous and speckled with fuscus black, also black markings as follows: A large one on dorsal line of head, several subdorsally and laterally on thorax, an irregular double line on abdomen above spiracles, continued on venter to sixth segment, dorsal claret line from anterior margin of third abdominal segment to posterior margin of seventh. The spiracles are small, narrowly elliptical, margins black. Wing and antennal cases reaching posterior margin of fifth abdominal segment, the former broadly rectangular. Short capitate hairs on head. Cremaster inconspicuous. The length of the pupal stage is 11 to 12 days.

*Moth.*—"Length 26–30 mm. Wings fuscous, in ♂ suffused with purple-blue except on termen, in ♀ on basal half only; hind wings with long linear terminal projection on 2, and a blackish subterminal spot on each side of it. Wings beneath pale brownish, with irregular partly connected white striæ; hind wings with white posterior fascia, and two black partly orange-edged spots, marked with pale metallic green-blue, before termen above tornus."[1]

The dry pods and seeds of legumes are attacked in storehouses and somewhat in the field by certain insects which habitually feed on stored products, notably bruchid weevils. Five species of this family have become established here. *Bruchis chinensis* and *B. prosopis* have bred from seeds of the pigeon pea, *B. chinensis* from seeds of the cowpea, and *B. prosopis* and *Caryoborus gonagra* from seeds of keawe (*Prosopis juliflora*). The prinid beetle *Catorama mexicana* has been bred from seed of the velvet bean and the common coffee bean-weevil (*Arœcerus fasciculatus*) from pigeon pea seed stored and in the field. (Fig. 4.)

The following minor pests have been observed: A thrips determined by Mr. E. M. Ehrhorn as *Trichothrips nigricans* is abundant in the blossoms of pigeon pea. *Xiphidium varipenne* probably sometimes feeds on legumes, but is largely carnivorous in habit. A red spider (*Tetranychus* sp.) has been noticed on the foliage. The broken stems are bored by bostrychids.

[1] Meyrick. Handbook of British Lepidoptera. London, 1895, p. 347.

In connection with the work outlined above some observations were made on the capsid bug *Hyalopeplus pellucidus*, which is commonly found on pigeon pea as well as on many other economic plants, notably cotton and hibiscus. It has usually been thought that this insect is at times predaceous, and having it on the authority of the late Mr. Kirkaldy and others, the writer so described it in a bulletin on cotton insects published several years ago.[1] But after taking the greatest pains to discover any predatory inclinations, he is inclined to think it nourishes itself entirely on plant juices. It has repeatedly been observed in all stages feeding on plants.

Kirkaldy[2] describes the ultimate and penultimate nymphal instars, but nothing is said of the egg or earlier stages. Several gravid females captured in the field and confined in breeding jars oviposited

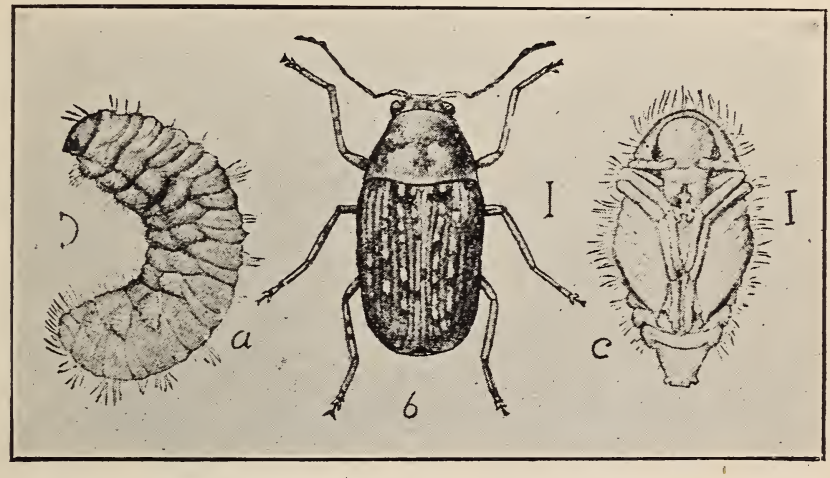



FIG. 4.—*Arœcerus fasciculatus:* Larva, beetle, and pupa.

a few days later and the process of egg laying was carefully noted. The eggs are inserted singly in the stems or buds, one female laying probably 15 or 20. They are about 1.4 mm. long, smooth, pearly white, and flattened cylindrical, slightly curved, with a spur outwardly on lower edge, which forms the scar. The egg stage occupies approximately 10 days. There are supposedly five nymphal instars as in other bugs, but only four were observed by the writer, the first apparently being missed. There is little difference in the earlier stages from those described by Kirkaldy, except in the shape of the body and the comparative length of body, beak, and antennæ. In the second instar the body is 1.5 mm. long, the antennæ 1.75 mm., second and fourth antennal joints subequal, third nearly 2, and the second 2½ times the first. The labium reaches nearly to the apex of the body which is covered with long fuscous yellowish pile. The

[1] Hawaii Sta. Bul. 18, p. 25.
[2] Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, p. 159.

pronotum is a little longer than the head and a little less than its apical width. The hind margin is subequal to the apical margin; scutellum indistinct.

In the third instar the body is 2.5 to 3 mm. long, the antennæ 2.5 mm., the relative length of joints very much as in later stages. The labium reaches the apex of the fourth sternite. In this and the preceding stage the markings are more extensive than indicated by Kirkaldy. The purplish-red or sanguineous medium percurrent or laterally sinuate lines on head reach slightly beyond the thorax, and on the abdomen on each side are five more or less distinct percurrent lines of sanguineous spots reaching to the apex, where they are more pronounced than in front. In this stage the wing bugs appear. The total length of nymphal life is 14 days.

## THE MEDITERRANEAN FRUIT FLY.

The recently introduced Mediterranean fruit fly (*Ceratitis capitata*), which was first noticed in the summer of 1910, is spreading rapidly on Oahu and gives every promise of becoming a serious fruit pest here as elsewhere. It has been bred so far from oranges, limes, pomelos, peaches, mangoes, guavas, and peppers. Citrus fruits and peaches around Honolulu seem to be generally infested. The insect, which is probably a native of Africa, but now widely distributed by commercial operations, resembles in a general way the melon fly, but is much handsomer in appearance. Its habits are very similar to those of the melon fly, the eggs being laid beneath the surface of fruits by means of the sting-like ovipositor. Infested fruits often show discolored spots on the surface. The maggots hatching from the eggs develop in the interior of the fruit, which gradually becomes putrid. Fruit infested on the tree usually falls early to the ground and the larvæ when full grown leave the fruit and enter the soil to pupate. The life cycle is said to cover about one month.

Little can be suggested in the way of remedial measures, as the fly reproduces itself so rapidly and so abundantly that, in countries where conditions are less favorable for its multiplication than they are in Hawaii, it is impossible to prevent great damage by the fly to the fruit crops which it infests. In South Africa it is partially controlled by the timely application of a light sprinkling of poisoned bait, consisting of 2 pounds of arsenate of lead and 25 pounds of sugar to 40 gallons of water, on the trees. In Hawaii, however, as pointed out by Dr. Perkins, the hive bee must be taken into consideration, many of which would also be killed by the poison, especially at such times as the algaroba and other flowers visited by the bees are out of bloom.

## REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

One of the chief lines of work that has occupied the attention of the horticultural department during the year has been on the avocado. Among other aspects of the subject, special attention has been paid to propagation, spraying for the control of a fungus disease and for a caterpillar, and also the study of varieties.

### AVOCADO INVESTIGATIONS.

Much attention has been given to the propagation of the avocado by budding, both at the station and elsewhere. Investigations have now been carried far enough so that methods of budding have been devised which are quite satisfactory. Some of the difficulties which have been encountered have been in the securing of good bud wood and the starting of buds into growth. Some old trees that are doing well in fruit production fail to produce a reasonable number of good buds. In the case of these it is sometimes necessary to prune a part of the tree rather severely to induce a growth of suitable bud wood. It has been found best to force newly set buds into growth by the incomplete girdling of the branch about 6 inches above the bud. It has not been very satisfactory to lop the avocado trees, as has been done with citrus. It has also been found to be an advantage to cover the entire bud with a wax bandage at the time of budding. With such precautions and working with good stocks, from 75 to 90 per cent of the buds may be expected to grow.

The spraying experiments, which have been carried on largely by Mr. Hunn, have been designed to determine the best methods for the control of a fungus disease which has been called "rusty blight" because of its effect upon the foliage, and also for the control of a leaf-folding caterpillar, *Amorbia emigratella*. The effect of some of these sprays is also being noted upon the avocado mealy bug, *Pseudococcus nipæ*. The four sprays used have been Bordeaux mixture and arsenate of lead, Bordeaux mixture and lime resin, self-boiled lime-sulphur and arsenate of lead, and a brand of commercial lime-sulphur and arsenate of lead, thus using a combined insecticide and fungicide.

Mr. Hunn has made an extensive study of the varieties of avocados growing in and about Honolulu. Between 65 and 70 varieties have been carefully studied and described. A number of these have

already been budded into the trees in the avocado orchard. This orchard is making normal growth, and a few of the trees are coming into bearing. These phases of the avocado work, as well as others, have been reported upon quite fully in a bulletin recently issued upon the avocado in Hawaii.[1]

Detailed outlines have been devised by Mr. Hunn for the description of varieties of avocado, papaya, mango, and hibiscus.

## PAPAYA INVESTIGATIONS.

### BREEDING.

The papaya investigations have been continued through the year. The work has included breeding, pruning, thinning, and shipping, and has been carried out by Mr. Valentine S. Holt, assistant in horticulture. The ultimate aim of a part of this undertaking is to work out methods for the breeding of varieties of desired qualities that can be depended upon to reproduce themselves with reasonable accuracy from seeds. It will be understood that there is no means available for the propagation of the papaya by asexual parts, as cuttings, buds, scions, etc., hence seed varieties must be established by methods probably similar to those used in breeding varieties of vegetables and flowers which are not propagated by budding and grafting.

The report for the year 1910 indicates the progress of the work to that date. It may be recalled that attention was then directed to the two most distinct forms of the papaya—the dicœcious and the moncœcious, with many apparently intermediate forms. Before entering upon a discussion it may be well to review this situation and note the significance of certain terms which have been adopted to designate the plants and flowers which enter into the work. Plate I shows the pistillate tree and flower representing the female element of the dicœcious type. This dicœcious type is the best-known form of the papaya. This pistillate tree, as is well known, produces the fruit. Plate II, figure 1, shows the staminate tree and flower of this dicœcious type and represents the male element. This tree also produces occasionally a flower containing both stamens and pistils, and therefore capable of producing fruit. These hermaphrodite flowers, however, are frequently distorted, and most staminate trees fail to produce them. Plate II, figure 2, shows a tree and also a larger view of the flower of the moncœcious type. It will be seen that the stamens are to be found attached to the inner walls of the corolla and quite close to the stigma.

Bearing in mind these distinctions, it may be recalled that in the last annual report a suggestion was then offered to the effect that it would probably be well to discontinue the use of the dicœcious type,

[1] Hawaii Sta. Bul. 25.


PISTILLATE PAPAYA TREE AND FLOWER OF THE DIŒCIOUS TYPE.

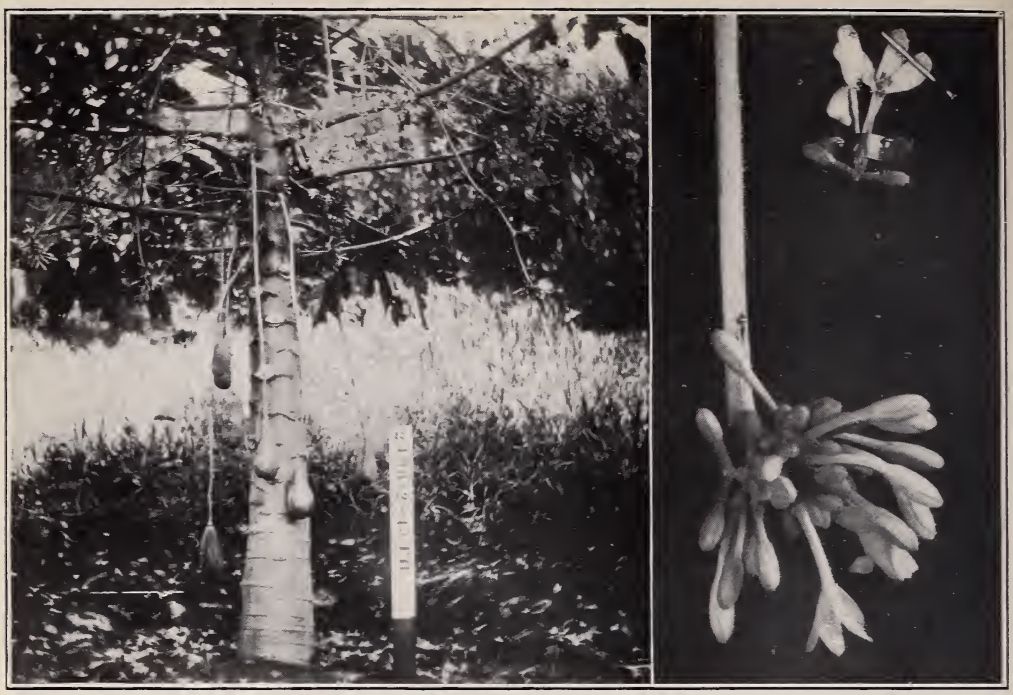


FIG. 1.—STAMINATE PAPAYA TREE AND FLOWER OF THE DIŒCIOUS TYPE.

FIG. 2.—PAPAYA TREE AND PERFECT FLOWER OF THE MONŒCIOUS TYPE.

except, possibly, in combining it with the monœcious, because of the unknown and probably unknowable characters of the staminate plant. But some of the papayas of the diœcious type have certain desirable characters which it would be an advantage to combine with a monœcious variety. This opens the whole question as to the possibilities of close and cross pollination in the papaya. In order to test this matter, 16 different possible combinations of pollen and stigma were tested, and some light has been obtained on the subject. These possible cross and self fertilizations were as follows:

(S)[1] 1. Perfect monœcious flower with its own pollen.

(U) 2. Perfect monœcious flower with pollen from a staminate flower from the same cluster.

(U) 3. Perfect monœcious flower with pollen from a staminate flower of another cluster on the same tree.

(S) 4. Perfect monœcious flower with pollen from a perfect flower on another monœcious individual.

(U) 5. Perfect monœcious flower with pollen from a staminate flower of another monœcious individual.

(S) 6. Perfect monœcious flower with pollen from a perfect flower on the so-called "male tree."

(U) 7. Perfect monœcious flower with pollen from a staminate male flower on the so-called "male tree."

(S) 8. Pistillate (diœcious) flower with pollen from a perfect flower of monœcious type.

(U) 9. Pistillate (diœcious) flower with pollen from a staminate monœcious.

(S) 10. Pistillate (diœcious) flower with pollen from a staminate tree ("male").

(U) 11. Pistillate (diœcious) flower with pollen from a perfect (hermaphrodite) flower occasionally found on the so-called "male tree."

(S) 12. Perfect or hermaphrodite flower on the male tree with pollen from a perfect flower of the monœcious type.

(U) 13. Perfect or hermaphrodite flower on the male tree with pollen from a staminate flower of the monœcious type.

(S) 14. Perfect or hermaphrodite flower on the male tree with pollen from the staminate flower from the "male tree."

(S) 15. Perfect or hermaphrodite flower on the so-called "male tree," with its own pollen (hand pollinated).

(S) 16. Perfect or hermaphrodite flower on the so-called "male tree," with its own pollen (sealed in sack but not hand pollinated).

Several questions are involved in each of these pollinations. Take, for example, the eighth pollination, or that of a pistillate (diœcious) flower with pollen from a perfect flower of the monœcious type,

[1](S) and (U) refer to successful and unsuccessful crossing.

which seemed perhaps the most promising means of combining any desirable character of the diœcious papaya with the monœcious, and out of this pollination will arise, among others, the following questions:

(1) Is it possible to make this cross?

(2) If this cross is possible, what will be the result in the sex of the progeny? Will there be a certain number of staminate trees and also pistillate and monœcious, or will some of the characters of the diœcious tree and some of those of the monœcious be combined in the offspring?

(3) To what degree will the characters of the female parent be reproduced in the monœcious offspring?

(4) Will it be possible by close pollination to preserve in future generations the monœcious character of certain members of the first generation of offspring if such appear? It will be remembered that the aim is to get back in breeding, as in commercial culture, to the monœcious type.

The work has already gone far enough to give definite answer to some of these questions and some light has been thrown upon others. For example, it can be stated definitely that the first question can be answered in the affirmative. It is perfectly possible to fertilize the stigma of a pistillate flower with pollen from a perfect flower of the monœcious type. Some light has been thrown upon the second question, but from its very nature it would be necessary to conduct a large number of tests extending over several years in order to establish any law governing the proportion of male and female and monœcious types resulting from such crosses. One year is a short time within which to get figures on this question. The striking fact, however, is that in the case of the eighth type of cross the resultants have shown a considerable proportion of monœcious individuals. Some of these resultants are intermediate in certain characters. While they produce flowers possessing both stamens and pistils which mature fruit, the stamens are less definitely located than in the case of the plant which we regard as the normal monœcious type. Plate III, figure 1, illustrates this condition. At "D" may be seen two flowers just beginning to develop into fruit. The one on the right has the stamens placed in the normal manner in the throat of the corolla to which they are attached. The upright one has dropped its petals, but the stamens may be seen still attached to the disk at the base of the ovary. This particular cluster of flowers came from a plant of unknown parentage, but illustrates the meaning of the statement that this flower and fruit are unlike the ordinary monœcious in form. The stamens are variously placed, in some cases being found on the lobes of the ovary. At "B" may be seen

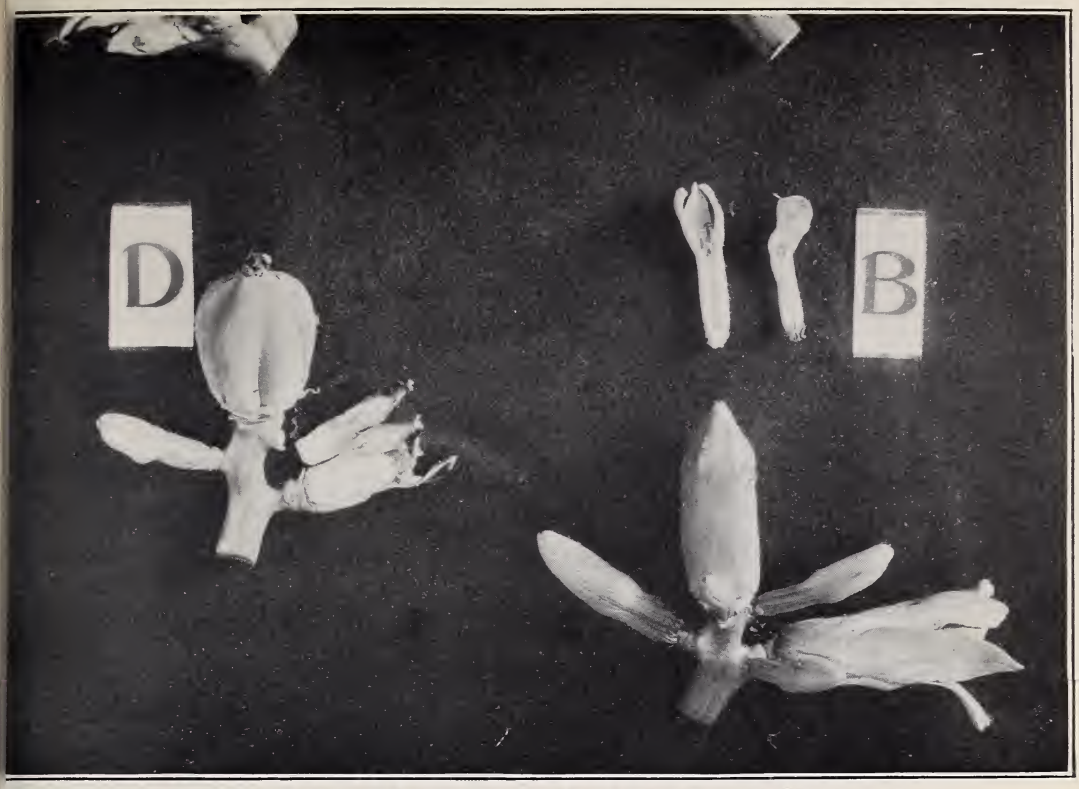



FIG. 1.—PERFECT AND MONŒCIOUS TYPES OF FLOWERS OF PAPAYA.

D. Two forms of perfect or hermaphrodite flowers in the same cluster. The lower flower to the right is of the normal form; the upper has the stamens at the base of the ovary, which is in shape like that of the dicœcious type. B. Staminate flower of the monœcious type above; normal cluster below.

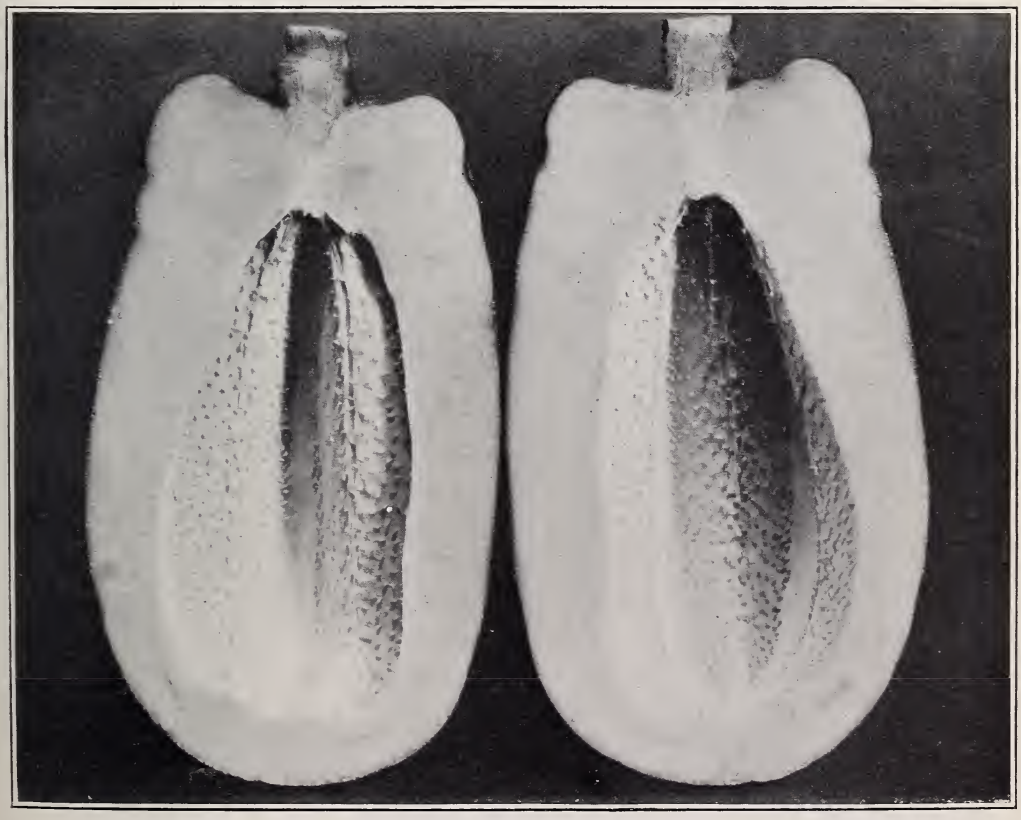


FIG. 2.—A SEEDLESS PAPAYA GROWN FROM AN UNPOLLINATED FLOWER.

the ordinary staminate flower of the monœcious type and below is a normal monœcious cluster.

It has been shown, then, that it is possible to make the cross to which reference was made in the annual report for 1910 and to get a fair proportion of monœcious trees in the offspring. The answer to the third inquiry, which has been raised, namely, to what degree the characters of the female parent will be reproduced in the monœcious offspring, must await the ripening of the fruit and then may be only suggested. The problem involved in the fourth inquiry must remain open for some time.

The same series of inquiries arose regarding the ninth combination where pollen of a staminate monœcious flower was applied to dicœcious stigma, and similar questions in relation to the other possible pollinations. In the list of pollinations (p. 27) those which have proved more or less successful are indicated by the letter "S," while those unsuccessful are indicated by the letter "U." It will be seen that the ninth and all other pollinations including the use of pollen from the staminate flower of the monœcious type have failed to fertilize the ovaries. This includes with the ninth, the second, third, fifth, and thirteenth. It would not be safe to conclude from the evidence now in hand that all of these combinations are impossible, but further studies of this pollen must be made.

Setting these aside for the present, therefore, some attention may be given to the result of other pollinations. The latter have been made too recently to have shown much beyond their ability to fertilize. The first and fourth have set fruit in a fair proportion of cases and these fruits probably contain seeds. The sixth has proved successful so far in one instance only. In this one fruit has set, but what the effect has been in seed production can not yet be determined. The same is true of the twelfth. A reasonable proportion of the pollinations of the fourteenth, fifteenth, and sixteenth types have been successful.

The tenth pollination is interesting in showing the effects of breeding within the dicœcious type. The progeny of one set of pollinations has been brought to fruit production. None of these plants shows any tendency toward the monœcious type. They include pure pistillate and pure staminate individuals only. This evidence, so far as it goes, is confirmatory of the theory that the monœcious and dicœcious types are rather distinct and that the intermediate forms are variants.

Early in the work it was discovered that a certain papaya tree growing on the station grounds was devoid of seeds in all fruits which were examined. It was desired to learn, first, whether this seedless condition is due to lack of pollination; and, second, whether it is possible for the papaya fruit to develop without the fertilization of the ovary. To get some light on these questions a number of

flowers of this tree were hand-pollinated with pollen from a staminate flower of the diœcious type. Several other flowers were sealed in paraffin sacks several days before opening to prevent pollination by natural means. All these flowers, both pollinated and unpollinated, developed into full-grown papayas.

Flowers on other trees have been sealed without pollination, but in most instances have failed to produce fruit, the pistils falling off within a week or two. On some trees, however, it has been found that sealed unpollinated flowers have produced normal papayas, except that they have been without seeds and have been smaller in size than the fruits from fertilized ovaries. (Plate III, fig. 2.)

From the above statements it seems justifiable to conclude, first, that pollination is not always necessary for the production of fruit in the papaya, and, second, that seedlessness in the case of the first tree mentioned above is probably not due to a lack of pollination, since the pollen used in the pollinations was of the type which usually gives good results and also because the flowers of this tree have the same opportunities to become fertilized as those of the surrounding trees which produce fruit containing seeds.

### PRUNING.

The papaya tree has some tendency to branch. The branches soon begin to bear fruit. This usually results in the production of a large number of fruits per tree, but they are likely to be small. Experience, therefore, at this station seems to indicate that to get large-sized fruit it is best to prune off these branches when they first appear, allowing the vitality of the tree to pass along the main trunk and develop its fruits.

### THINNING OF THE FRUITS.

One of the characters of some papaya trees is to set very many more fruits than there is room for on the trunk. A large number of such trees have been found among the crosses referred to (p. 27) under the eighth type of pollination. Such fruits can never develop normally in size or shape, but crowd each other and thus become distorted. In the case of such trees it has been found necessary to thin the fruits, leaving usually only one fruit to each flower cluster or in the axil of each leaf.

### SHIPPING EXPERIMENTS.

Several years ago this station, in connection with other fruit-shipping investigations, made trials of placing this fruit in several markets on the Pacific coast. It was taken to San Francisco and thence as far north as Vancouver, B. C., where a fair proportion of

it arrived in good condition, notwithstanding the lack of refrigeration on the rail journey, unusually warm weather, and delays in transit. It was apparent, however, that there are marked differences in the carrying qualities of papayas from different trees, some being unsuitable for shipment.

At the time referred to the station was not growing papayas in sufficient quantity for shipping tests and the supply available was such as could be found in small orchards supplying the Honolulu market. Recently the trial shipments have been resumed in a very small way by sending to San Francisco a few papayas grown at the station grounds. The purpose was to further test in general the possibilities of placing this fruit in the mainland markets and in particular to make trial of the carrying qualities of some varieties that are being grown at the station.

This work was undertaken prior to the recent quarantine regulations of the State of California, which temporarily prohibit the importation into that State of all fruits from Hawaii except bananas and pineapples. The fruit fly has not been found in the papaya, and it may be demonstrated that it does not injure this fruit. Until this matter is settled, no shipping of papayas to the mainland can be done; but the results of the work are herewith published for the significance which they have upon the papaya as a shipping fruit wherever grown or marketed.

The fruits were forwarded in refrigeration per steamship *Sierra*, sailing from Honolulu on April 19 and arriving in San Francisco on April 25. All the fruits were beginning to ripen when they were gathered from the trees, most of them exhibiting only the first indications of yellowing. They were gathered on the day preceding that of the sailing of the ship and were packed in excelsior in open crates, each fruit having been wrapped in paper.

These experiments were upon a small scale, but so far as they go their indications are the most favorable of any papaya shipments that have been made from this station. The reports received from those to whom the fruits were sent indicate that with the exception of one fruit the papayas were too green to be eaten on arrival in San Francisco, and a period of 5 to 12 days elapsed before they became sufficiently ripe in ordinary air temperatures. Considerably less time than this would be sufficient to distribute the fruit through the various channels to the consumer and would also offer the opportunity for a permanent supply with steamers sailing not more frequently than at present. Peaches, cherries, and other fruit that would not stand so long a period are shipped by carload lots across the American continent.

The indications are that, as the papaya industry develops, in Hawaii or elsewhere, there will prove to be at least three important factors in the successful placing of these fruits in distant markets. One of these is on the side of production. It will be necessary to grow varieties that have good carrying qualities. Papayas differ greatly in this respect, and one of the problems upon which the station is now working is to select, segregate, and if possible improve varieties that possess these qualities in a high degree. The experiments indicate that some degree of success has already been attained. In order to make the work successful in the largest way, it will be necessary not merely to select trees of the desired qualities but to establish varieties so that they can be depended upon to reproduce their characters.

The second factor in successfully shipping papayas to the mainland is on the side of packing. The fruits must be gathered at the right time and must be carefully handled and packed, wrapping each fruit in paper and surrounding it with sufficient packing material to prevent bruising and yet not interfere with refrigeration. The crate should be open so as to permit the rapid cooling of the fruit, which should be put into refrigeration as soon as possible after picking.

The third factor pertains to the proper distributing of the fruits. Papayas are unknown on the mainland except to the few who have visited Hawaii or some other tropical land. If placed in the usual wholesale market, the fruit would probably rot before a buyer would appear who knows the papaya. Therefore some other means of finding the consumer and of developing the taste among those unfamiliar with the fruit must be devised. In some markets there are dealers who make a specialty of handling rare and unusual fruits, and they have their special class of customers. Where such dealers are not to be found it would seem best to begin with large hotels and fashionable clubs and restaurants. With these special arrangements could be made to receive small shipments regularly and thus build up a market.

### MISCELLANEOUS WORK WITH PAPAYAS.

Other miscellaneous work with the papayas during the year has included the combating of insects, including cutworms, the small larva of the genus Amorbia, which hides among the flowers and emphasizes the need of thinning them, and black and green aphids on fruits; and the collecting and drying of the milky juice of the fruit which has been carried on only in a preliminary fashion.

## INVESTIGATION OF BANANAS IN HILO AND OLAA, HAWAII.

Early in December a letter was received from Hon. L. A. Thurston, general manager of the Hilo Railroad, reporting certain difficulties

with the Bluefields banana in Hawaii. It was stated that this variety of banana was failing of success because of the breaking off of the pseudostems and the falling of bunches. It was also stated that the same difficulty was found with another banana which had been introduced into Hilo from the district of Hamakua, probably 12 or 15 years ago, and is reported to have been brought to Hamakua by the captain of a ship which anchored off this coast. This latter variety has been regarded by some observers as being identical with the Bluefields.

In view of the recent revival of interest in the banana industry it was deemed important to investigate this matter. The horticulturist proceeded to Hilo on December 13, returning December 17.

It was found that a very large percentage of the Bluefields plants in some localities broke or bent over; in other places this was not so common. There appeared to be several causes at work contributing to this trouble. It does not appear to be due to any inherent weakness of the variety; nor, we believe, to any lack of adaptability to Hawaiian conditions. Some of the causes at work appear to be as follows:

(1) Close planting. The practice in vogue in the planting of the Chinese and other small growing varieties had been adopted for the Bluefields. It was found that they are being planted as close as 6 by 6 feet in some cases, and the widest planting found was about 10 by 10 feet. This variety has been found to do best at 12 by 15 or as wide as 15 by 15. The close planting makes too dense a foliage and the plants become thin stemmed and spindling, as is the case with most plants that are crowded and reaching upward in the effort to get light.

(2) The bunches are left upon the plant until they become extremely large and heavy. On one plantation the writer was informed that from 90 to 100 pounds was the average weight of the bunch when cut. On another plantation the information was given that one bunch had weighed as high as 140 pounds. It is the custom in Hawaii to leave the bunches on the plants until they are almost ripe. In this way they acquire their full flavor, but in commercial growing for export such bunches would decay before reaching the market. This variety of banana, as grown in the West Indies and Central America, is cut some time before it has attained its full weight.

(3) Lack of pruning. It was found that the pruning off of the dead leaves has not been practiced. These are allowed to fall back against the pseudostem. This adds to the darkness in which the pseudostem is confined and it also retains moisture. It appears also that this may be a contributing cause of the failure of the plant to sustain its load of fruit.

### SEARCH FOR BANANA DISEASE.

A search was made for plants which might show indications of the banana blight, now prevalent in the West Indies and Central America, which is believed to be due to a Fusarium. No certain evidence of this disease was found. In one field the plants were reported to have died back in a manner somewhat similar to that of bananas affected with Fusarium. These plants, however, were growing in grass and had not the opportunity to flourish. Some of the plants showed discolorations in the pseudostem which looked somewhat suspicious. Material was collected from a number of plants which showed more indications of the disease than any others, and this material has been forwarded to the Department of Agriculture in Washington to be submitted to specialists in this disease. The final report upon this material has not yet been received.

### THE SO-CALLED HAMAKUA BANANA.

This banana, as has been stated, was brought to Hilo from Hamakua. The writer saw it growing in Hilo in 1904 and it was, at that time, reported to have been there some years. It has been regarded by some as identical with Bluefields, and in some cases no attempt has been made to distinguish between the two in planting. A search was made for bananas having fruits which might be known to have come directly from the Hamakua stock. Some were found which the writer was assured had grown from this stock. A careful comparison was made between these and the Bluefields. The Chinese variety was also brought into the comparison of flavor and texture. The fruits of the Hamakua lack the characteristic aroma of the Bluefields and resemble closely in flavor the Chinese variety. In form and coloring they are much like the Bluefields. The specimens in hand were larger than any Bluefields that could be found, yet this difference would not be sufficient in itself to show that the two are not identical. The conclusion was reached that the so-called Hamakua banana, while distinct from the Bluefields, resembles it so closely that the two could probably be marketed as the same variety.

The opportunity was not afforded to compare the two in relation to other characters. One of the strong features of the Bluefields banana, as grown in Central America, is its shipping quality. This is very essential in any commercial banana. Whether the Hamakua would prove a good shipper, or not, can not be stated, and for this reason, if for no other, intending planters should confine their commercial plantings to the Bluefields and the Chinese varieties, which are known to stand transportation.

## THE GRAPE.

There is a small grape industry in Hawaii. Grapes are grown for home use in almost all parts of the islands at the lower elevations. In and about Honolulu and Hilo they are grown to supply the local market for fresh grapes, while in Makawao on Maui, and also in Hilo and Kona on the island of Hawaii, there is a small wine industry.

The last session of the Territorial legislature requested the station to prepare a small press bulletin on the growing of the grape in Hawaii for publication in the Portuguese language, since the industry is almost entirely in the hands of the Portuguese. Some investigation was made of the methods in vogue and the difficulties which have been met with by those engaged in the business, and a small pamphlet on the subject was issued.

## THE MANGO.

### NEW VARIETIES.

The work with the mango has continued along much the same lines as formerly, and, with the exception of spraying experiments, little new work has been undertaken. The working of new varieties into the orchard by budding and grafting has been continued. Some of the new varieties have been coming into bearing during the year. One of the most striking of these is the Brindabani. Perhaps the most distinctive features of this variety are its peculiar form, its heavy bearing habits, and its coming into bearing at a remarkably early age. It came into the bearing of mature fruit within 18 months from the date of grafting. The tree at 2½ years old from scion and bearing its second crop of fruit is shown in Plate IV. The fruit had been severely thinned to prevent the breaking of the tree.

MANGIFERA INDICA. Indian variety Brindabani.

*History.*—The original stock was received in May, 1908, from the Bureau of Plant Industry of the Department of Agriculture as an inarched pot plant. This plant was inarched upon a seedling mango tree in the orchard on December 12, 1908, produced its first crop in the summer of 1910 and its second main crop in 1911.

*Description.*—Form roundish oblate; size medium, averaging 8 to 9 ounces; cavity shallow, flaring, irregular; stem slender, persisting well; apex depressed; surface smooth and undulating; color green, blushed with orange and red, being a rich orange yellow when exposed to the sun and mature; dots yellow, small, very numerous, and slightly raised; bloom bluish white, quite abundant; skin moderately

thick, tough, tenacious; flesh moderately thick, orange yellow, coarse, juicy, with an abundance of fiber; seed reniform and rather thin; flavor sprightly, a trifle acid, and quite pleasant; quality fair to good. Season July to September for the main crop at Honolulu, Hawaii.

The tree is small of stature and has a broad spreading habit, lower branches often sweeping the ground. (Hunn.)

THE OAHU.

*History.*—A seedling tree about 6 or 7 years of age bore fruit this year, and its characteristics have given justification for naming it Oahu. It is probably a cross between the Hawaiian sweet mango and the Crescent. Although the husk is present, the seed presents an undeveloped condition with often just the seed coat present. About 75 per cent of this year's crop has had no viable seed. (Pl. V.)

The Oahu is valuable as a large, fine-appearing fruit of good quality. Its nearly seedless condition makes a thin husk with a large proportion of flesh. No mango weevil, *Cryptorhynchus mangiferæ*, has been found within these mangoes, and it will be interesting to note what may be the result of the attack of this insect on a fruit which contains no seed upon which its larva may feed. The Oahu is also worthy of propagation as a basis for breeding toward complete seedlessness.

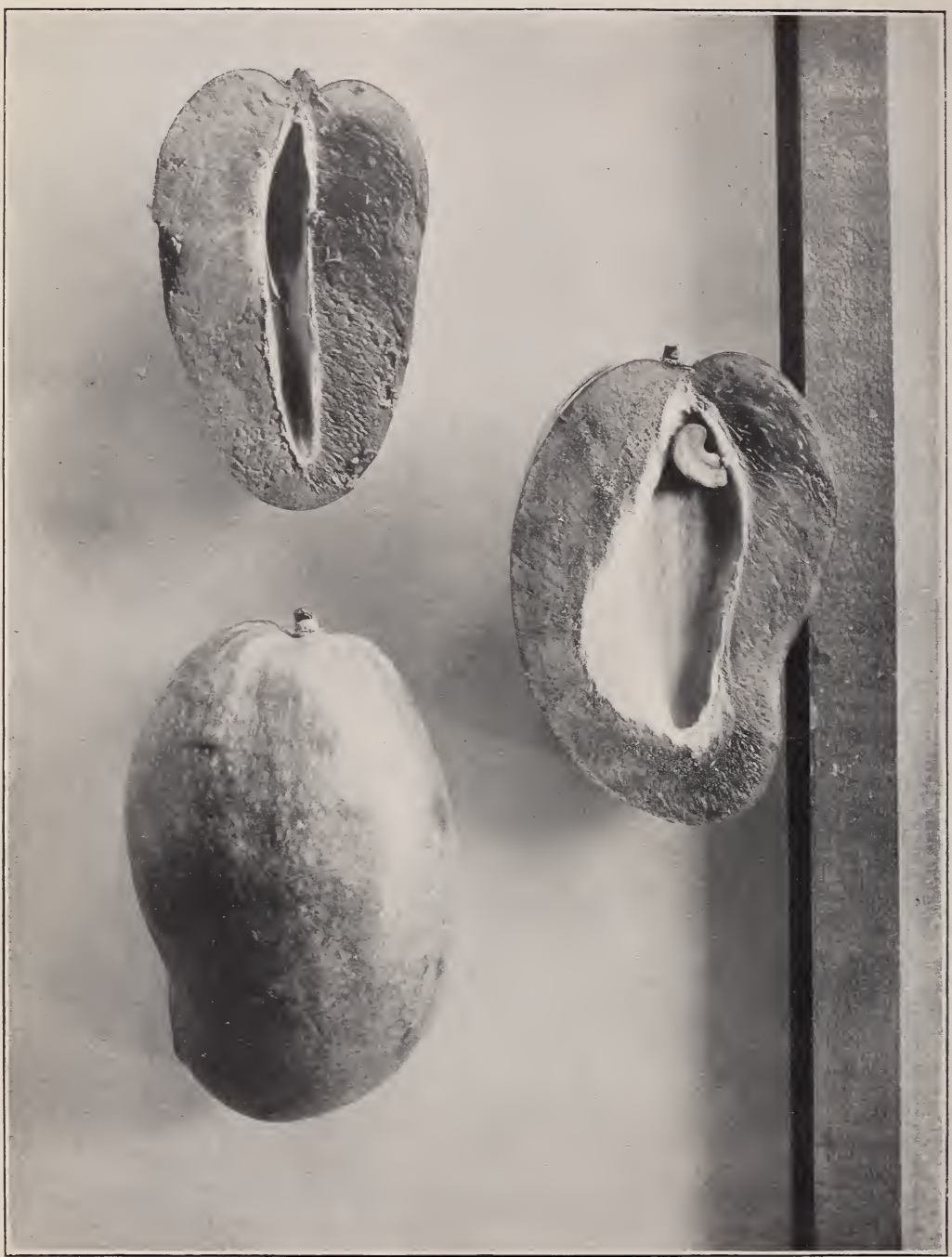
*Description.*—Form oblong, heavily shouldered at the cavity end and tapering toward the apical end; size large, averaging in weight from 10 to 15 ounces; cavity shallow, flaring, irregular; stem slender; apex variable, ranging from a point to a depression; surface moderately smooth and undulating; color pale yellow with a reddish blush on the exposed side; dots numerous, small, yellow, depressed; bloom bluish white, moderately abundant; skin moderately thick, tough, very tenacious; flesh thick, bright yellow, juicy, with an abundance of fiber; seed dried up or represented by just the seed coat; flavor rich, moderately sweet; quality good. Season June to August at Honolulu, Hawaii.

This tree is of the average height and presents a broad spreading habit. (Hunn.)

## SPRAYING.

The mango in Hawaii is quite seriously attacked by a fungus disease sometimes called mango blight and which is due to the fungus *Glœosporium mangiferæ*. This disease causes the destruction of the flowers, the young foliage, and sometimes the young twigs. It also results in the spotting and rotting of the fruits of susceptible varieties. The same leaf-folding larva to which reference was made when

THE BRINDABANI MANGO BEARING ITS SECOND MAIN CROP OF FRUIT 2½ YEARS AFTER GRAFTING.



THE OAHU, A NEARLY SEEDLESS MANGO.

discussing the avocado also attacks the mango, its chief damage being done to the flowers and young fruits. Spraying experiments along the same lines as indicated in the case of the avocado have been carried on. It has not been found difficult in years past to control the disease with Bordeaux mixture, but because of red spider and thrips which sometimes infest the mango it was thought well to make some tests of the sulphur sprays also. The results of these spraying experiments, as well as the methods upon which they have been carried on, are given in detail, so far as they are at present available, in Bulletin No. 25 of this station, on the Avocado in Hawaii.

## FRUIT MODELING.

Fruit modeling as a means of record has been used to some degree in the study of mango varieties. Modeling has some advantages over photographing or verbal description as a permanent record. The method used was applied at the station first by the late Mr. F. N. Otremba, who was an expert in this line of work. The method, however, is so simple and convenient that it does not require artistic talent to use it successfully. Other members of the staff have found it convenient, and it might be worth while here to record the method for the convenience of others who may wish to apply it.

The principle involved is simply to make a mold by pouring a medium of glue and gelatin about the fruit to be modeled. This when cold is cut open and the fruit removed, leaving the mold, into which plaster of Paris is placed in a liquid form and allowed to solidify, making the cast. The details are as follows:

*The mold.*—This is formed of fish glue and gelatin. The glue should be reduced to the liquid form with water by being heated in a kettle surrounded by water and placed over a slow fire. When liquefied add the gelatin. About 1 pound of gelatin to 2½ pounds of glue has been satisfactory.

*The box or container.*—This may be made of wood, but we have found that for fruits of ordinary size a flower pot can be used very conveniently and saves much trouble. If made of wood, the box must be held together by wire or twine so that it can readily be taken to pieces. A flower pot has the advantage of being larger at the top than at the bottom and therefore the mold can be removed without great difficulty. The inside of this container must be well coated with shellac and each time before the mold is made must be well oiled. A mixture of 50 per cent olive oil and 50 per cent kerosene is, perhaps, most satisfactory, but cottonseed or ordinary raw linseed oil would probably serve the purpose.

*Making the mold.*—Oil the fruit to be modeled and place it in the container, which should be large enough to allow an inch or more on

each side of the fruit and between the fruit and the bottom. The fruit may usually be suspended from a small nail driven through a stick which rests upon the top of the pot and is tied down at the ends to the shoulder of the pot. This will prevent the fruit from rising to the surface when the glue is poured into the container. While the glue is warm, but not too hot, pour it into the container, distributing it on all sides so as not to crowd the fruit to one side. Allow it to remain so overnight. In the morning remove the mass of glue from the container. With an oily knife cut one side of the mass from end to end or as far as may be necessary. Gently release the fruit and remove it, leaving the mold empty. At the same time cut a small opening at the highest point to receive the plaster of Paris. Allow the mold to dry for half an hour and then apply to its interior, with a brush, a coating of about 10 per cent formalin to harden the surface.

*Making the cast.*—After the formalin has evaporated apply a coating of oil to the interior of the mold and also oil the interior of the container into which the mold must now be placed. It is sometimes necessary to tie the mold together before replacing it in the container. Take the required amount of plaster of Paris and add to it enough water to make a thick liquid. Mix this well so as to free it from all lumps and pour it into the mold through the opening made in the top. Shake the mold with a circular motion to force the plaster of Paris into all parts. Allow it to stand for an hour or more when it will be sufficiently solidified to be removed. It may then be taken out with the same care with which the fruit was removed.

*Coloring the cast.*—If it is desired to have a reproduction of the color of the fruit as well as the form, this may be done with water colors, but for this part of the work some familiarity with color work will be necessary. Any slight imperfections must first be removed. Sometimes minute holes, which have failed to be filled by the plaster of Paris, are to be found. These may be filled by first dipping the cast in water and then painting it with a very dilute coat of plaster of Paris. These may not be filled by one or two coatings, but care must be taken not to alter the shape of the fruit. To prevent the colors from striking into the cast it is necessary to coat the latter with a very thin glue, applied with a brush, after which the colors may be applied.

## CITRUS FRUITS.

The citrus orchards have been extended somewhat during the year. A number of new varieties have been budded into the orchards and nurseries. There are now growing on the station grounds the follow-

ing varieties of citrus trees, of which quite a number budded in 1909 are in fruit at this writing:

ORANGES. (29 varieties, 126 trees.)

Bouquet des Fleurs.
Centennial.
Dancy Tangerine.
Dugat.
Du Roi.
Enterprise Seedless.
Golden Buckeye Navel.
Golden Nugget Navel.
Hart Tardiff.
Jaffa.
Joppa.
King Mandarine.
Lamb's Summer.
Magnum Bonum.
Majorca.
Maltese Blood.
Mediterranean Sweet.
Paper Rind St. Michael.
Parson Brown.
Pineapple.
Ruby Blood.
Satsuma.
Scented Orange.
Tangerine.
Thompson Improved Navel.
Valencia Late.
Variegated Navel.
Washington Navel.
Navelencia.

POMELO. (11 varieties, 59 trees.)

Duncan.
Imperial.
Whitney Imperial.
Marsh Seedless from California.
Marsh Seedless from Florida.
McCarty.
Pernambuco.
Royal.
Tresca.
Triumph.
Woodworth.

LEMON. (6 varieties, 35 trees.)

Seedless Campucinni.
Eureka.
Genoa.
Lisbon.
Ponderosa.
Villafranca.

LIME. (2 varieties, 6 trees.)

Kusaie.
Tahiti.

CITRON. (1 variety, 1 tree.)

Citron of commerce.

## ACCESSIONS AND DISTRIBUTIONS.

### ACCESSIONS.

Among the numerous accessions of the year a few should receive special mention. Seeds of the date palm (*Phœnix dactylifera*), said to be of unusual merit, were collected by Dr. Wilcox in Arizona

during the early part of the year. These are reputed to be of a strain which produces good fruits from seed. They have germinated well and will be soon ready for planting out.

The *Agava lespinassei* and *A. zapupe* were received from the Office of Foreign Seed and Plant Introduction, Department of Agriculture. Most of these were given into the custody of Mr. William Weinrich, manager of the Hawaiian Fiber Co.'s plantation on this island, where they will be propagated and from which source the station can secure plants for distribution if desired later. A few of the plants were retained on the station grounds.

A new variety of pigeon pea known as Cadios was received from the Philippine Islands.

Plants of *Canarium commune*, S. P. I. No. 25684, were received by mail and are recovering from the effects of this long transportation.

*Greigia sphacelata*, a decorative bromeliad related to the pineapple, was received from the same source as the above. The fruit of this species is said to be held in high esteem in Chile.

Several species of Anona have been received and planted.

Bud wood of a number of varieties of citrus was received from Mr. G. P. Wilder, who collected them on his tour around the world. These included a seedless lemon called the Capucinni, and bud wood was received from Kauai of a variety of orange known as the Scented Orange, which was observed by the horticulturist several years ago, and which had the finest color of any orange that he has seen growing in Hawaii.

## DISTRIBUTIONS.

Quite a large number of plants have been propagated and distributed during the year. The chief purpose of this has been to introduce certain varieties of plants and disseminate them more widely in the Territory. Among these have been the Merced variety of sweet potato. This is probably the same variety as is known in the East under the name "Jersey Sweet." Reference was made in the last annual report to the possibilities for marketing this variety of sweet potato on the mainland. In order to assist in this matter, plants or roots have been distributed to all who have applied. Something over 3,000 plants have been sent out besides a number of shipments of roots.

Banana offsets have been distributed in considerable numbers. The supply of the Bluefields variety, for which there is a great demand, has become so reduced that the distribution of these has been suspended for the present. It is hoped that these will soon be sufficiently disseminated in the islands so that the station will no longer need to engage in the distribution.

About 300 seeds of *Aleurites cordata*, one of the wood oil nuts, were received from the Office of Foreign Seed and Plant Introduction, Department of Agriculture, and were distributed to several parts of the islands, where it is thought they will have the best chance to prosper. The same species has been planted at several times on the station grounds, but this locality does not seem to be well adapted to the plant.

The orchards and nurseries of the station have now grown sufficiently so that it has been possible during the past year to distribute citrus bud wood to all who have applied. This material has been of several varieties.

In connection with the papaya work reported above, about 250 packages of best selected seeds have been distributed and about 9 pounds of ordinary selected stock.

The *Carissa arduina*, a new fruit and ornamental shrub described in the report for 1910, has been distributed to the extent of over 2,000 plants and many packages of seeds.

The roselle has been sent out in about 80 packages. This plant is now rather widely disseminated and it does not seem necessary for the station to longer engage in its distribution.

Numerous requests have been received for seeds of pigeon pea and cowpea for windbreaks and cover-crop purposes, and over 200 pounds have been distributed.

## HIBISCUS.

Mr. Valentine S. Holt, assistant in horticulture, donated to the station his private collection of hibiscus. A small amount of time has been devoted to the breeding of new varieties of this most ornamental plant. There are probably few, if any, plants of more promise for ornamentation in the islands than the hibiscus. The plant grows in comparatively dry and poor soil and has been planted at the station in places formerly occupied by weeds and lantana and where little else would prosper. While there may be some who will think that the hibiscus is of little economic importance it may be said that its popularity is evinced by the large demand for varieties of this genus. The first Hawaiian exhibition of hibiscus was held during the month of June, 1911, and astonished even those most familiar with these plants by the number and beauty of the varieties which were brought together. The station cooperated in this undertaking by exhibiting its flowers. Over 3,000 cuttings of different varieties have been sent out. A method has been adopted in this propagation work by which the plants can be multiplied rapidly at nominal expense. Cutting beds of ordinary beach sand have been prepared in the open. The cuttings are tied up in bunches

of 50 to 100 and planted in the sand where they root readily. They are thus rapidly put in and can be rapidly removed.

## NEEDS.

The chief needs of the department of horticulture at the present time are increased facilities for propagation. On this subject, Mr. Hunn, who is in charge of the propagation work, submits the following data:

> During the year I presented you a lengthy report of the condition of affairs in regard to our present situation and facilities for seed and plant propagation. A resubmission of this report with added emphasis would be in place at this time. Our facilities are inadequate to successful propagation. There is no usable means by which to obtain bottom heat so needful in propagation work. The temperature can not be regulated. Protection is almost nullified by our present appointments, while diseases, insects, and rodents must be constantly combated. The condition in the potting room remains the same, while the shade houses are deteriorating. We have had to brace some of the walls of the shade houses and have removed benches which were rotten and of no further use.
>
> The situation has been partly relieved by the erection of six outside benches—each 18 feet long and 4 feet wide. The supports were erected in pots which are kept constantly filled with water, thus making the benches ant proof. A woven-wire box, 8 meshes to the square inch, 2½ feet high, has been built on each bench. These benches were primarily erected for the purpose of hardening off plants and to protect them against ants and rodents. Circumstances have compelled us to use them for propagation benches.

The need for better facilities for propagation has certainly become imperative. There is no glass house in the horticultural department and no means by which delicate plants can be protected from heavy rains. The shade houses, which have been very satisfactory for older and more established plants, are now in a dilapidated condition and are liable to fall down in any storm. It is hoped that some arrangement may be made for this work.

In closing it is desired to express appreciation of the very faithful services of Mr. C. J. Hunn, assistant horticulturist, and Mr. Valentine S. Holt, assistant in horticulture.

## REPORT OF THE CHEMIST.

By W. P. Kelley.

The work of the chemical department during the year has been devoted to soil investigations, plant physiology, and miscellaneous analyses.

### SOIL INVESTIGATIONS.

The soil investigations have been continued along the lines suggested in the previous report. The conditions in certain cultivated sections of the islands, together with the experience of farmers and members of the station staff, have convinced us of the need for an investigation of soil factors not commonly studied in agricultural investigations. The difficulties attending the continued cultivation of pineapples on Oahu and the failure to manage successfully some of these soils by the use of the usual cultural methods and fertilizers indicate that other factors demand attention. These investigations have been along two general lines, which may be classified as physical and chemical. The study of soil physics has been conducted with special reference to the movement of water in certain types.

For a considerable time it has been apparent that one of the fundamental difficulties in pineapple cultivation is faulty drainage, and it already appears that if a permanent system is to be evolved under the prevailing climatic conditions, it is necessary more thoroughly to comprehend the physical factors involved. The results thus far obtained have a direct application to the pineapple soils of Oahu. In addition it is believed that these soils offer opportunities for studies of a scientific nature, the result of which may have a much broader application. In certain of these soils physical factors play an abnormal part in their productivity, but it is also likely that in such instances there is only an exaggeration of what exists in soils throughout the islands and to some degree everywhere.

#### THE MANAGEMENT OF SOILS.

It is commonly held that the free circulation of soil moisture is indispensable to the normal growth of higher plants. All plants, however, are not equally sensitive to adverse physical conditions. The pineapple is a particularly sensitive plant and often fails to vegetate as a result of a number of causes. Among the easily recognizable causes of failure, the lack of sufficient drainage is one of the most

apparent. Usually cultivation and frequent tillage accelerates drainage by keeping the soil open and preventing its becoming compacted. At the same time a loose soil is more retentive of moisture in times of continued dry weather.

The frequent and thorough tillage of certain pineapple lands in the Wahiawa district is sometimes attended by a retardation of the movement of soil water during times of wet weather. The chief cause of this condition has been found to be associated with the fact that sufficient care has not been exercised in the cultivation of these soils. At various times during the year continued rains bring about saturation of the soil, at which times the growth of weeds is very rapid. The farmers feel compelled to cultivate at such times before the soil becomes properly dried out. This cultivation has resulted in puddling the soil to such an extent that natural drainage is greatly hindered.

Particular emphasis has been placed on this phase of the question in a previous publication devoted to the management of pineapple soils.[1] In addition the investigation has led to a further study of the movement of water in other soils in the islands.

## CAPILLARY RISE OF MOISTURE.

If we are to understand the peculiarities of these soils and foresee what will be the results of a given treatment, it is essential to understand the fundamental movement of water in them. Ordinarily soils contain four kinds of water, namely, water of chemical combination, such as enters into the composition of clays and other hydratable substance; hygroscopic water; capillary water; and free circulating water. The first two of these will not be discussed at this time further than to point out that the chemically combined water in pineapple soils appears to be abnormally high, the explanation of which, however, is found in the physical composition. Frequently these soils contain from 30 to 50 per cent of finely divided substances, ordinarily called clay, a large part of which contains water of hydration.

Capillary water or moisture except in times of wet weather forms the nutrient solution in which the several mineral substances necessary to plant growth are dissolved. Such water comprises thin films which more or less completely envelop the soil particles, connecting them, and the movement of which is dependent upon various conditions. The force which brings about movement in this moisture is usually referred to as capillary attraction and is caused by surface tension. The capillary movement of soil moisture in other countries has been investigated to some extent. The soils throughout Hawaii, however, are unlike ordinary soils in a number of particulars. Their chemical composition is different and the physical make-up unlike

[1] Hawaii Sta. Press Bul. 29.

that of most soils. It is therefore of some scientific interest to determine the relative movements of water in these soils. In addition, such a study is of practical importance to the pineapple growers.

In this investigation soils of widely different physical structure have been used. The following table shows the relative percentages of the different-sized particles contained in the samples used:

*Mechanical composition of soils.*[1]

| Serial number. | Loss on ignition. | Fine gravel. | Coarse sand. | Fine sand. | Silt. | Fine silt. | Clay. |
|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 7 | 13.14 | ..... | 0.77 | 3.64 | 8.85 | 34.54 | 36.28 |
| 9 | 16.77 | 0.87 | 8.20 | 22.44 | 13.94 | 23.13 | 13.11 |
| 15 | 16.66 | 2.54 | 6.28 | 21.17 | 14.57 | 21.90 | 15.50 |
| 61 | 25.16 | .12 | 7.20 | 40.90 | 9.85 | 15.01 | 2.93 |

[1] Analyses made by the method of Hall. The Soil. London, 1908, 2. ed., p. 51.

Finely pulverized air-dried soil was prepared by rubbing samples in a mortar with a rubber pestle so as to reduce the larger aggregates without crushing the ultimate particles. Portions were then inserted into glass tubes 4 feet in length and 1 inch in internal diameter by the use of a long roll of paper, by means of which the soil was introduced into the tubes in such a way as to leave it in an unbroken column. In order to prevent the soil from falling out the lower end of the tube was closed by a piece of fine muslin stretched over it. These columns were suspended in such way as to allow the lower end to dip beneath the surface of distilled water. The upward capillary rise of moisture could be easily observed by the wetting of the soil and was measured from time to time. The following table shows the results:

*The capillary rise of moisture in soils.*

| Time. | Heavy clay No. 7. | Silty soil No. 9. | Silty soil No. 15. | Highly organic sandy soil No. 61. |
|---|---|---|---|---|
| | *Centimeters.* | *Centimeters.* | *Centimeters.* | *Centimeters.* |
| 10 minutes... | 5.5 | 7.5 | 6.5 | 7 |
| 20 minutes... | 7 | 9.5 | 9.5 | 9.5 |
| 30 minutes... | 8 | 11 | 12 | 11.5 |
| 45 minutes... | 9 | 12 | 14 | 13.5 |
| 1 hour..... | 10 | 13.5 | 15.5 | 15.5 |
| 2 hours..... | 11.5 | 16.5 | 20 | 20 |
| 3 hours..... | 13 | 19.5 | 22.5 | 24 |
| 4 hours..... | 14 | 21.5 | 24 | 27 |
| 5 hours..... | 15 | 23.5 | 26.5 | 29.5 |
| 6 hours..... | 16 | 24.5 | 28 | 31.5 |
| 1 day..... | 22 | 37.5 | 41 | 48 |
| 2 days..... | 24 | 41 | 45 | 57 |
| 3 days..... | 24.5 | 43.5 | 52 | 63.5 |
| 4 days..... | 25 | 44.5 | 55 | 66.5 |
| 5 days..... | 26 | 45 | 57 | 69.5 |
| 6 days..... | 27 | 45 | 58 | 74.5 |
| 7 days..... | 27.5 | 48 | 60 | 77.5 |
| 8 days..... | 27.5 | 48 | 62 | 79.5 |

These data show that the upward capillary movement of water in these soils varies between wide extremes. It was found to be greatest in sample No. 61, which is a highly organic soil from the Kula district of Maui and contains a very small percentage of clay. Next in the upward movement are soils Nos. 15 and 9, both of which are composed largely of silts and fine sand. The most retarded capillarity

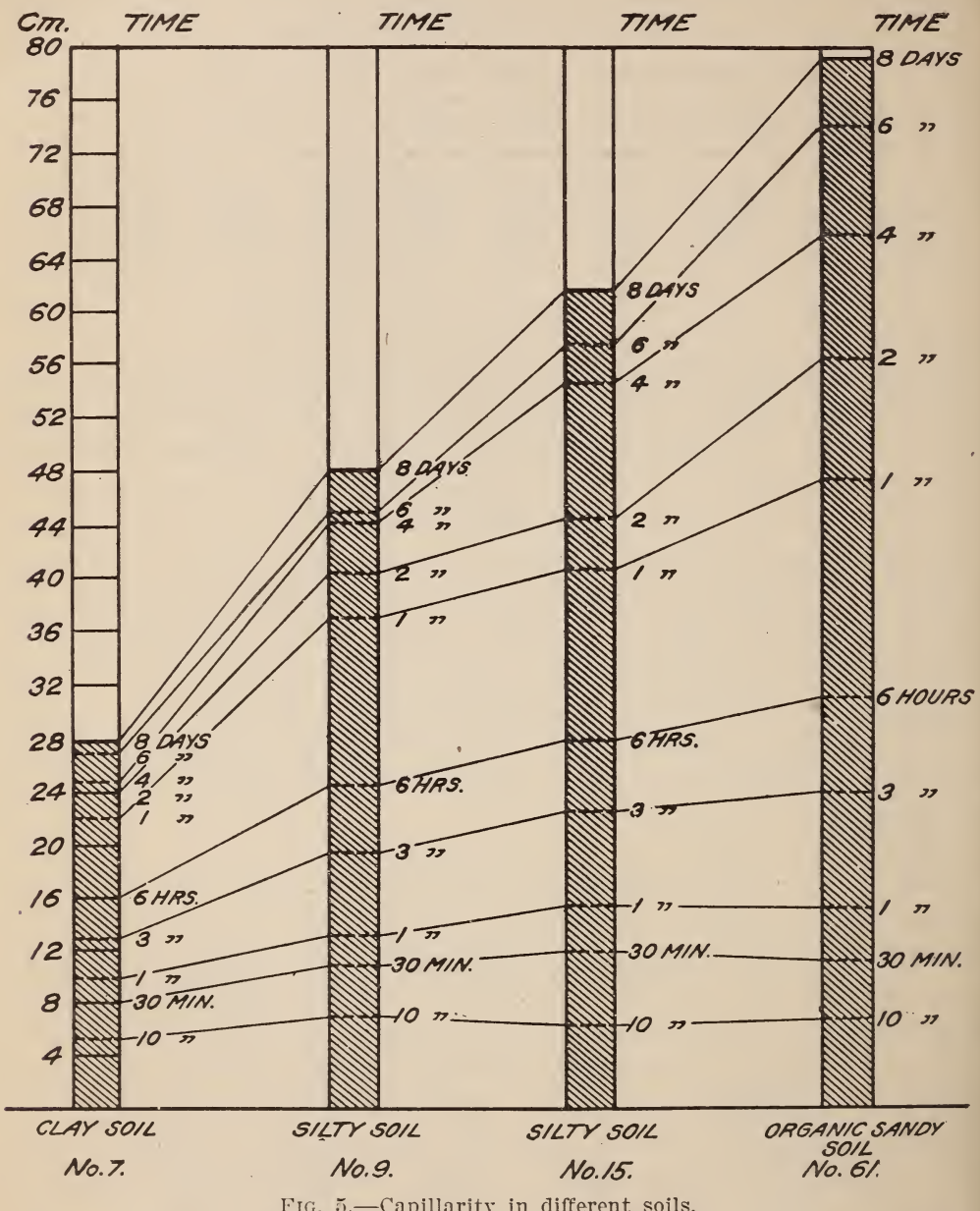



Fig. 5.—Capillarity in different soils.

was found in soil No. 7, a heavy clay. The capillarity in the different soils is diagrammatically shown in figure 5.

From this investigation it is shown that the capillarity, and hence the power to maintain a good moisture content during continued dry weather, varies in these soils between wide extremes. Clay should have a greater capillarity than coarser particles, and therefore water

ought to rise to a higher level in clay soils if other factors were not involved. Loughridge [1] has shown, however, that the rate of capillarity is proportional to the size of the particles, while the maximum height to which water will rise is greater in the silts. Clays when moist gradually become colloidal, and in consequence offer resistance to the passage of water by increasing the friction, which finally becomes sufficiently great to balance the force of capillarity. The amount of colloidal clay in soils is not always proportional to the percentage of clay found by mechanical analysis and, further, clays of different sorts become colloidal in varying degrees.

It should not be considered that the conditions in these experiments exactly duplicate those of the field, and consequently the movement of water herein reported is not the same as takes place in the field. On the other hand, however, the data are comparable and give an idea of the relative movements that take place under natural conditions. The general field observations are in accord with the experimental findings.

In addition to the upward capillary movement of soil moisture there is also what is known as downward capillarity. With a view of determining the rate at which this movement will take place, an additional set of tubes prepared as above were kept under a constant water head of 1 inch. The following table records the results:

*Downward capillarity in soils.*

| Time. | Heavy clay No. 7. | Silty soil No. 15. | Organic sandy soil No. 61. |
|---|---|---|---|
| | *Centimeters.* | *Centimeters.* | *Centimeters.* |
| 5 minutes.... | 8 | 10 | 9 |
| 15 minutes... | 15 | 16 | 14 |
| 25 minutes... | 19 | 20 | 19 |
| 45 minutes... | 25 | 26 | 25 |
| 1 hour..... | 29 | 29 | 32 |
| 2 hours..... | 44 | 45 | 45 |
| 3 hours..... | 61 | 60 | 60 |
| 4 hours..... | 74 | 76 | 69 |
| 5 hours..... | 80 | 80 | 76 |

The downward capillarity of these soils is thus shown to be essentially the same. In addition the movement under the conditions of the experiment was very much greater than was the capillary rise. These data, however, should not be interpreted to mean that the downward flow of soil water is the same in these soils. The rate at which water will flow through the soil in addition to the capillary movement of moisture forms a more adequate basis for conclusions regarding drainage. In order to determine the percolating power of these soils the same tubes used in the last set of experiments were

[1] California Sta. Rpt. 1904, p. 33.

allowed to stand until the downward movement of moisture had reached the bottom of the tubes, after which the amount of water which drained through was collected in graduated cylinders and measured.

*Percolation through soils.*

| Time. | Heavy clay No. 7. | Silty soil No. 15. | Highly organic sandy No. 61. |
|---|---|---|---|
| | *Cc.* | *Cc.* | *Cc.* |
| 1 hour | 10 | 22 | 15 |
| 2 hours | 11 | 40 | 30 |
| 3 hours | 12 | 57 | 45 |
| 4 hours | 14 | 70 | 58 |
| 5 hours | 16 | 80 | 72 |
| 1 day | 66 | 155 | 184 |
| 2 days | 93 | 222 | 407 |
| 4 days | 136 | 363 | 817 |
| 5 days | 155 | 435 | 1,095 |
| 6 days | 170 | 508 | 1,215 |
| 7 days | 182 | 586 | 1,345 |
| 8 days | 190 | 662 | 1,490 |
| 9 days | 196 | 741 | ..... |
| 10 days | 210 | ..... | ..... |
| 11 days | 218 | ..... | ..... |
| 12 days | 226 | ..... | ..... |
| 13 days | 235 | ..... | ..... |

These data indicate the relative rates of drainage that would be expected to take place in the field. As already stated, soil No. 7 is a heavy clay, having been taken from a field in which natural drainage is very poor. By comparing the mechanical composition and the percolation, it is seen that the soils containing the highest percentage of clay and fine silt permit the flow of water through them at the slowest rate. The air spaces in soils of high clay content are small in size, so that the capillary force, being proportional to the surface, is also great; but the resistance offered to the movement of water is, on account of friction, relatively greater in clay soils. The clay in soil No. 7 is not composed of silicate of aluminum alone but contains a very high percentage of iron, the analyses of which have shown as high as 35 per cent $Fe_2O_3$. A part of this iron exists as ferric hydrate, which, in addition to containing water of hydration, becomes gelatinous when wet, thus further inhibiting the free movement of water through it. Also we have evidences of the existence of a double silicate of iron and aluminum, which compound is colloidal and very finely divided and appears to have a tendency to reduce the flow of water through the soil even more than ordinary clay.

The accompanying diagram (fig. 6) shows the rate of percolation through different soils.

The samples used in the previous experiments were thoroughly air dried at the outset and it was observed that the percolation was greater at the beginning than toward the end of the experiment. This may be taken as evidence of the gradual hydration of colloids, which by somewhat swelling tend to hinder the free passage of water.

From the data it appears that drainage would gradually become slower during a long-continued wet season, especially in soils similar to No. 7. In the more porous soils, however, such effects would not be observed. The subsoil underlying No. 7 also contains a very high percentage of clay, which makes natural drainage more difficult. In addition the organic matter of this soil is low.

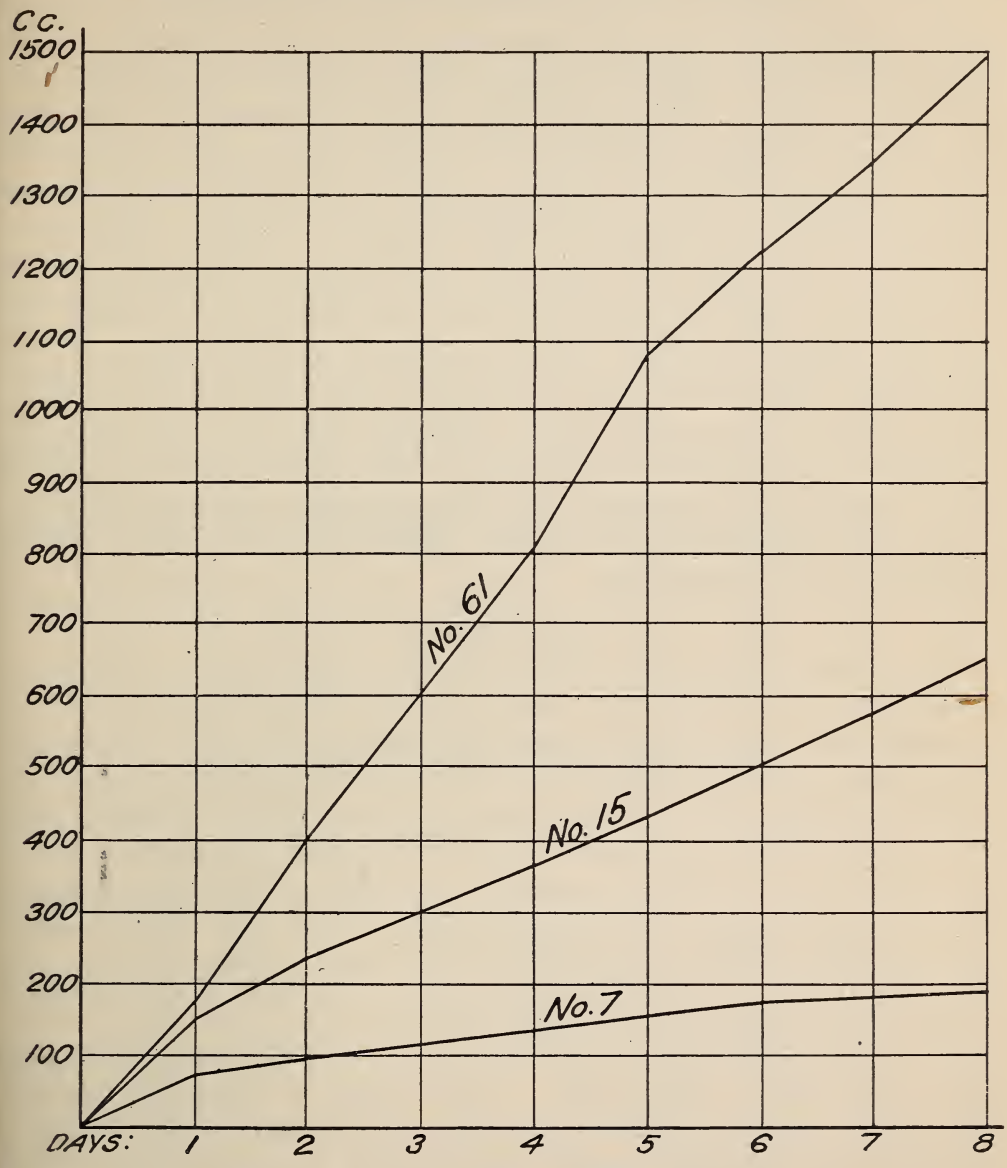



FIG. 6.—Percolation through different soils.

The management of soils similar to No. 7 requires the greatest of care if good tilth be maintained. Under no circumstances should they be tilled when wet and, in addition, crops should be rotated and organic manures and green manuring crops used as often as possible. By increasing the organic matter of such soils, a granulation of the clay can be gradually effected and at the same time greater porosity and better natural drainage will result.

## SOIL ORGANIC MATTER.

An extensive study of the several methods previously used in the determination of the so-called humus in soils has been made by Mr. W. T. McGeorge, assistant chemist, and the results of this investigation are now being prepared for publication. In this paper it will be shown that none of the methods usually employed in this determination can be relied on with Hawaiian soils. A modification of the Cameron-Brazeale method, however, has been found to be both accurate and practical. Hawaiian soils contain abnormally large percentages of an extremely finely divided ferruginous clay which will remain in suspension in an ammoniacal extract indefinitely and can not readily be removed by ordinary filtration, sedimentation, or coagulation. The use of a clay filter, modified so as to prevent the absorption of organic matter and at the same time overcome any dialyzing effect, has been found to be effective and practical. In this connection some attention has been given to a study of the organic matter of Hawaiian soils, and sufficient data have already been obtained to warrant the conclusion that the organic matter of these soils is made up of extremely complex mixtures, varying from soil to soil, and perhaps different in some degree from the organic matter of soils of older formations.

## SOIL SURVEY.

Samples of soil from the various sections of the islands are being collected from time to time, and chemical and physical analyses are being made as fast as opportunity permits. This work will be continued until the soils from all the important upland districts have been systematically examined. Previous classifications of the island soils have been of a very general nature, and, with the exception of the sugar lands, no systematic effort has been made toward the classification and grouping of the soils. With the advance of diversified agriculture into the previously unoccupied lands, information concerning the composition and properties of these soils becomes of greater importance. A classification and survey of these soils in the sense it is understood in older countries may never be possible, but a general survey and location of local types and the study of their properties will undoubtedly be of great use to future agriculturists.

In this work new and rare types have already been discovered. In addition to the highly manganiferous soils of Oahu, the occurrence of an extensive body of highly titaniferous soil has recently been found. Samples have been analyzed which, in some instances, contain 20 per cent titanium, expressed $TiO_2$. This soil has peculiar properties which are of both practical and scientific interest. Other

sporadic soils having abnormal properties have also been found. Sufficient data have already been accumulated, therefore, to justify the conclusion that the upland soils of the several islands present a range of variation in composition and properties by no means common on such limited areas.

## FERTILIZER EXPERIMENTS WITH COTTON.

In cooperation with the agronomist, fertilizer experiments with cotton have been conducted for the past two years. The results obtained are fairly concordant and will perhaps be of some interest to the cotton growers of the islands. These experiments were conducted on the lands of the Kunia Development Co. and the upper portion of the Oahu Sugar Co.'s land, both on Oahu, and in each instance dry-land culture was employed without the use of artificial irrigation. The small yields are in part due to the lack of sufficient moisture, and the effects of the several fertilizers, while relatively striking, would no doubt have been greater under more moist conditions. Fertilizers to be of the greatest benefit require an abundance of moisture in the soil. In some instances the application of fertilizer to pineapples at the beginning of a dry season produced little effect, and examination some weeks later showed the fertilizer to be apparently unchanged in the soil. In other instances near by a similar application, when followed by sufficient rains, brought about excellent growth. The Seabrook strain of Sea Island was used in these experiments with the following results:

*Yields of seed cotton in fertilizer experiments.*

| Fertilization.[1] | Size of plat. | Kunia. | | Waipahu. | | | |
|---|---|---|---|---|---|---|---|
| | | 1909 | | 1909 | | 1910 | |
| | | Yield per acre. | Increase per acre. | Yield per acre. | Increase per acre. | Yield per acre. | Increase per acre. |
| | *Acre.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| Check | 3/40 | 240 | ..... | 119 | ..... | 147 | ..... |
| Superphosphate, sulphate of potash | 3/40 | 347 | 16 | 218 | 88 | 220 | 105 |
| Dried blood, superphosphate | 3/40 | 416 | 85 | 217 | 87 | 267 | 152 |
| Dried blood, sulphate of potash | 3/40 | 307 | ..... | 66 | ..... | 103 | ..... |
| Check | 3/40 | 320 | ..... | 66 | ..... | 83 | ..... |
| Dried blood, superphosphate, sulphate of potash | 3/40 | 470 | 139 | 278 | 148 | 257 | 142 |
| Ammonium sulphate, superphosphate, sulphate of potash | 3/40 | 480 | 149 | 440 | 310 | 190 | 75 |
| Nitrate of soda, superphosphate, sulphate of potash | 3/40 | 450 | 119 | 572 | 442 | 313 | 198 |
| Check | 3/40 | 353 | ..... | 161 | ..... | 100 | ..... |
| Dried blood, basic slag, sulphate of potash | 3/40 | 453 | 122 | 356 | 226 | 263 | 148 |
| Dried blood, dicalcic phosphate, sulphate of potash | 3/40 | 490 | 159 | 546 | 416 | 352 | 237 |
| Dried blood, superphosphate, sulphate of potash, lime | 3/80 | 587 | 256 | 665 | 535 | 353 | 238 |
| Lime | 3/80 | 427 | 96 | 197 | 67 | 133 | 18 |
| Check | 1/10 | 412 | ..... | 174 | ..... | 132 | ..... |

[1] The fertilizers were applied so as to provide the following quantities per acre: Nitrogen, 20 pounds, phosphoric acid, 50 pounds, and potash, 30 pounds.

From these data it is clear that phosphates are the most needed fertilizing material in these soils and that there is some difference in their relative values. Dicalcic phosphate appears to have been somewhat more effective than other forms. These soils contain considerable phosphoric acid, but it is very largely combined with iron and alumina in extremely insoluble combinations.[1] It is likely that an easily soluble phosphate, like superphosphate, would tend to combine with the iron and alumina of these soils, forming difficultly soluble compounds, to a greater degree than the less soluble dicalcic phosphate. Potash and nitrogen, unless applied in conjunction with phosphates, produce little effect, and on the Waipahu experiment nitrate of soda was more effective than other forms of nitrogen. Lime likewise was ineffective when applied alone. The greatest yields in each instance were obtained by the combination of lime and a complete fertilizer. The experiment at Waipahu in 1910 was a continuation of that in 1909, the same plats being used in the two years, and the cotton was grown as a perennial. The fertilizer at the beginning of each of these experiments was applied in the furrows before planting. In 1910 the fertilizer was applied in February around the old plants and thoroughly worked into the soil. The total yields do not fully explain the noticeable effects from the treatment, for the plats treated with phosphates came into picking earlier than the others and yielded a greater percentage of their total harvest in fewer pickings than the unfertilized plats. Credit is due and thanks are here extended to Mr. F. G. Krauss and Mr. C. A. Sahr for cooperation in these experiments. The success of the trials was made possible largely as a result of their cooperation.

## RICE INVESTIGATIONS.

The fertilizer experiments with rice have been continued as in previous years and with similar results. In these experiments two crops of rice have been grown on the same land each year, and where ammonium sulphate was applied to each crop before planting the yields have been fully maintained. By the application of fertilizer to the spring crop only, however, the yields are gradually becoming smaller. The plats to which no fertilizer has been applied have become so reduced in crop-reducing power that an unprofitable yield is now being obtained.

The experiments with different forms of nitrogen have been concluded and the results published.[2] In these experiments it was shown that ammonium sulphate is a suitable fertilizer for rice, but nitrate of soda is ineffective. By the use of pot experiments it was deter-

[1] Jour. Indus. and Engin. Chem., 2 (1910), p. 277.
[2] Hawaii Sta. Bul. 24.

mined that rice absorbs nitrogen largely from the ammonium form and that if nitrates constitute the only form of combined nitrogen accessible to rice poor growth and unhealthy plants result. Rice appears not to have the power properly to transform nitrates into proteids.

## INFLUENCE OF MANGANESE ON PLANTS.

The investigation on some of the functions of manganese in plant growth have been continued throughout the year, and the results are being prepared for publication in a bulletin on this subject. In this investigation it has been found that manganese affects the mineral balance in practically all plants examined, and causes the plants to take up an abnormal amount of lime and smaller amounts of phosphoric acid and magnesia than are absorbed normally. Not all plants are equally sensitive to manganese, and a number of species show no visible effects from it. Further discussion of this question is reserved for the subsequent publication.

## REPORT OF THE AGRONOMIST.

By C. K. McClelland.

In the agronomy division experiments with rice and with cotton have continued to be the principal work undertaken, while those with alfalfa, soy beans, peanuts, and other legumes, also with corn and sorghum, have been of secondary importance. During the year the retiring agronomist prepared a bulletin upon Leguminous Crops for Hawaii, and also a press bulletin upon Peanuts in Hawaii.[1]

### RICE EXPERIMENTS.

The work continues with rice because of its importance in Hawaii, and with a hope that in the near future locally grown rice may regain the former importance in home consumption which it seems to have lost. Attention is called to the fact that rice is the only subsistence product raised in large amounts which is consumed by the "foreign" class of people, which class greatly outnumbers the native or taro-consuming class. So that if at some future time imports into the islands should for any reason be cut off, the rice crop would be the means of preservation of the foreign population, which without rice would, so to speak, be threatened with starvation. As noted in previous reports, the conditions surrounding the rice industry are very peculiar, in that, though the Chinese are the principal growers of rice, the Japanese are by far the largest consumers, and as they prefer Japan rice the imports of rice from Japan increase yearly.

The reasons given for this in the 1908 report were lack of flavor, strength, richness, or fattiness in the Hawaiian-grown rices, even in Japan varieties produced here. Chemical analyses made by the Bureau of Chemistry of the United States Department of Agriculture show that what little difference there is in composition is in favor of the Hawaiian rices. Another reason given the writer is to the effect that upon cooling the Hawaiian rices fall apart and become dry and rubbery, while the Japan rice, which in cooking also retains its individuality of kernel, upon cooling is held together and does not become dry and rubbery. Furthermore, the Japanese, being a very loyal people, prefer to spend their money in helping their countrymen who are the growers, importers, and transporters of this rice.

[1] Hawaii Sta. Bul. 23 and Press Bul. 29.

Whatever may be the reason, the actual facts are that Japan rice is consumed by the Japanese and in smaller amounts by the whites; while the Hawaiian Gold Seed or Chinese varieties are consumed by the Chinese and whites or shipped to California for the Chinese there.

In order to procure, if possible, a rice that would satisfy the taste of the Japanese consumers, the former agronomist visited Japan and brought back several of their better varieties which have now been grown at the station through three generations. The following table shows a comparison in yields between these and a former importation which has been grown here for several years but which seems to have deteriorated in quality:

*Yield of Japanese varieties of rice grown at the station.*[1]

| Varieties. | Spring, 1910. | Fall, 1910. | | Spring, 1911. |
|---|---|---|---|---|
| | | Fertilized. | Unfertilized. | |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| Benkei | 4.00 | 20.00 | 18.00 | 63.25 |
| Miyako | 3.75 | 19.00 | 18.25 | 74.75 |
| Omachi | 4.87 | 18.00 | 20.00 | 95.25 |
| Shinriki | 4.23 | 24.00 | 20.50 | 82.50 |
| No. 153 (old variety) | 4.15 | 14.25 | 11.75 | 100.00 |

[1] The areas were different for different seasons, but the same for all varieties for each season.

Of these rices the Miyako is the only one which has been produced in sufficient quantity for a culinary test. A resident of Honolulu who lived for many years in Japan reports this rice, as grown in Hawaii, "to cook as well as the imported Japanese rice, and, also, when cold, it keeps its moisture, which the Hawaiian does not do. It has not the oily strength of the native Japanese rice, but in taste and appearance quite equals, I think, the native rice of Japan." By another year it is hoped to have had all of these varieties tried out and thoroughly tested by the Japanese themselves.

In the spring crop of 1911 two variations were noticed from the growth of these rices: The Benkei variety developed a heavy tillering habit, which the Shinriki seems to have lost; and the Omachi, which is a bearded rice, was almost entirely beardless. If the latter rice will not deteriorate in quality under Hawaiian conditions it will no doubt be the rice to grow in these islands. Small lots of seed of all these rices were given to several growers, but it is difficult to get any of them to undertake any experiment with small lots of seed.

For the fall crop of 1911 a considerable quantity of the Omachi and of the Shinriki have been put out for trial, and a test of these can soon be made. The old variety, No. 153, was a selection from an importation made from Japan by a Chinese rice grower. This rice, as before stated, seems to have deteriorated in quality in the several

years during which it had been grown in Hawaii, and because of this and partly for other reasons enumerated above, it has sometimes been sold at a loss to the producer, which fact has discouraged the Chinese growers, until it is very difficult indeed to get them to test any other Japanese variety, fearing a like result.

Ten varieties of Formosan rices were received for trial and were given their first test in the spring of 1911.

An experiment in planting 1, 2, 3, 4, and 5 seedlings in a clump resulted in nothing definite, as a different number proved the best in each different variety tried.

The fertilizer and rotation experiments with rice are being continued in the same manner as mentioned in the previous report.

## COTTON EXPERIMENTS.

Because of the awakened interest in cotton the station has continued experiments with this crop along the lines mentioned in the previous report. The work with the Sea Island and Caravonica varieties has been of the greater importance, although that with other varieties has been no less interesting. It would seem from the experience with the cotton crop that the thing, more than all others combined, which will determine whether or not cotton is to be a profitable crop in Hawaii is success in controlling insect pests. Cutworms eat off the young seedlings, aphids cover and by their voracious attack stunt the young plants; then when in bloom the mealy bug, the cotton bollworm, and the leaf roller become serious pests.

### COOPERATIVE EXPERIMENTS.

The cooperative experiment at Waipahu was planned as a fertilizer test in 1910, but some of the results showing a comparison of varieties may be given here:

*Comparative yields of cotton.*

| Varieties. | Area. | Yield of seed cotton. | Yield of lint. | Percentage of lint to seed cotton. |
|---|---|---|---|---|
| | *Acres.* | *Pounds.* | *Pounds.* | *Per cent.* |
| Sea Island | 1 | 202.66 | 54.66 | 27 |
| Caravonica | 1 | 66.12 | 25.37 | 38.37 |
| Egyptian | 1 | 343.75 | 115 | 33.4 |
| Chinese upland | 1 | 546 | 180.83 | 31.1 |

It will be noticed that all of the yields are rather low. The upland, as one would expect, shows the greatest yield, and the Sea Island, which one would look for in the lowest place, outyielded the Caravonica. By referring to the previous annual report it is found that the Caravonica gave the lowest yield in the first year of these tests and also in a similar one at Kunia.

The location seems to have been unfavorable for cotton, as there was only about 40 per cent of a stand reported, and of that the bollworm is said to have taken 30 per cent. It was noticed that the damage was considerably less upon the upland than upon the other varieties. In another experiment with Caravonica transplanted seedlings gave much better results than those not transplanted.

### EXPERIMENTS WITH CARAVONICA COTTON.

About an acre of land at an elevation of 250 feet was planted February 4 and 5, bloomed by July 1, and was picked in six and eight pickings between October 1 and December 24, the bollworm infestation varying from 5 per cent in the third to 15 per cent in the sixth picking. The results were as follows:

*Yield of Caravonica cotton.*

| Number of plants. | Yield of seed cotton. | Number of bolls per pound. | Yield of lint. | Percentage of lint to seed. | Length in 16ths inch. |
|---|---|---|---|---|---|
| | *Pounds.* | | *Pounds.* | *Per cent.* | |
| 628 | 424.12 | 90 | 153.25 | 30 to 37 | 21 to 30 |
| 1 | [1] 0.67 | 60 | 0.244 | [1] 36 | [1] 24 |
| [2] 680 | 469.8 | ..... | 165.9 | ..... | ..... |

[1] Average. [2] One acre planted 8 by 8 feet.

These results, as calculated to a full acre, show quite an improvement over those at Waipahu, although only in the first year, when Caravonica is noted for its shy bearing. The length and the percentage of lint are very good, while an average of only 90 bolls to the pound of seed cotton is unusually low. This cotton was grown on the station grounds in a place quite well protected from the wind, which indicates that much better returns are to be expected when this variety is planted in protected places.

### PRUNING OF CARAVONICA COTTON.

From December 5 to 8, after the sixth picking, 312 of these plants were cut back very severely; some high pruned at about 4 feet and others low pruned at about 2 feet. From the pruned branches the cotton was picked as it matured. Strength tests of fibers thus matured and picked show a gradual weakening of the fiber; i. e., the more immature the fiber or boll at pruning time the weaker the fiber in comparison with fibers matured upon the plant in the natural way.

The balance of the field was pruned back the first week in March of the present year to test the effect of different dates of pruning. The December pruning made a vigorous growth in the spring and pinching was done upon both the high and low pruned trees (leaving

some as checks in both instances), some at squaring time, and upon others not until the flowering stage. A pruning test of the Caravonica cotton and an extensive cooperative experiment have been attempted upon the plan and theory given below.

Seedlings are to be pruned when about knee high—this checks the leading stem and induces branching. The first branches are usually vegetative branches and from these grow out the fruiting branches proper.

To induce these and also to check the vegetative branches the latter are pruned when it is thought that sufficient growth has been made. Other fruiting branches spring from the first ones, and an occasional pinching back is thought to favor the production of fruiting wood and thus of squares, and at the same time to restrain the tree-forming tendency. (See Pl. VI, figs. 1 and 2.) The results of this pruning were well demonstrated in the field of Caravonica, where the shape of the trees has been determined and the size largely controlled by this method, while squares were formed earlier and in greater abundance. However, the attacks of the bollworm have been so great that a comparison of the final results will not be conclusive. As a result of their work it is safe to say scores of squares, blooms, or small bolls have been shed, and many of those that escaped at first ripened prematurely as the result of a later attack.

There seemed to be two distinct squaring periods in these plants during the spring months, with an interval of perhaps 35 days between. At the first picking, made about June 1, the percentage of bolls infested by bollworms averaged 68 per cent. It was thought that by giving the plants an annual cutting back, as described above, the bollworm could be held in check, and the infestation soon fell to about 20 per cent.

Later information upon this point is to the effect that the idea of controlling the bollworm by an annual pruning is in the main correct, but the partial failure this year to accomplish the desired result is due to the fact that the prunings were made at different times, thus allowing a breeding place for the worm, first at one side of the field and then at the other. To make the work effective the pruning should be done over a large area at the same time and the prunings burned at once to destroy the larval and pupal stages of the insect. Any larval or mature form that is left will find no bolls or blossoms in which to feed and will consequently perish.

At Makaweli, upon Kauai, the 1910 crop was mostly destroyed by the worm, following two prunings in the field at different times, while the 1911 crop, which followed one complete pruning and burning, promises to be almost entirely free from bollworm.

Upon the windward side of Oahu also there are three plantings upon a considerable scale which were given this thorough pruning

FIG. 1.—PRUNED CARAVONICA COTTON.

FIG. 2.—UNPRUNED CARAVONICA COTTON.

COMPARISON OF PRUNED AND UNPRUNED CARAVONICA COTTON.

and burning at one time, and all of these are now comparatively free from the insect.

### MISCELLANEOUS EXPERIMENTS WITH CARAVONICA COTTON.

To reduce the damaging effects of the bollworm it has been found that the use of a trap, consisting of a lantern elevated above a pan of water and kerosene in the field at night, has been of material benefit, catching as many as 50 moths per night, the greater catch being made upon the stiller nights. By the use of the lantern and by cutting off and burning the infested bolls regularly the percentage of infestation in the field was reduced from 68 per cent in the first picking to 50 per cent in the second and to 26 per cent in the third picking.

Some selections were made from the field mentioned above and the yields from the individual plants were as follows:

*Yield of Caravonica cotton plants.*

| Plant No. | Number of bolls. | Yield of seed cotton. | Yield of lint. | Percentage of lint to seed. | Length in 16ths inch. |
|---|---|---|---|---|---|
| | | *Pounds.* | *Pound.* | *Per cent.* | |
| 0 | 281 | 1.92 | 0.63 | 32.9 | 24 |
| 1 | 65 | .9 | .33 | 37.1 | 21 |
| 2 | 149 | 1.42 | .48 | 33.5 | 25 |
| 3 | 211 | 1.64 | .57 | 34.7 | 26 |
| 4 | 203 | 1.87 | .68 | 36.3 | 22 |
| 5 | 449 | 3.26 | .98 | 30.0 | 30 |
| 6 | 331 | 2.79 | .99 | 35.6 | 24 |

A study of this table shows great variation in yield, in percentage of lint, and in length of staple. However, each plant showed a marked superiority over the average run of plants in the field. Selection "0" shows a trace of Egyptian blood and selection "5" a trace of Sea Island, indicating the mixed parentage and great variability of Caravonica cotton.

As showing the possibilities of Caravonica, the following results will be of interest:

*Yield of individual Caravonica cotton plants.*

| Row. | Plant No. | Number of bolls. | Yield of seed cotton. | Yield of lint. | Percentage of lint to seed. | Number of bolls per pound. |
|---|---|---|---|---|---|---|
| | | | *Pounds.* | *Pounds.* | *Per cent.* | |
| 26 | 1 | 569 | 6.56 | 2.73 | 41.6 | 87 |
| 26 | 2 | 446 | 4.23 | 1.72 | 40.6 | 105 |
| 26 | 3 | 300 | 2.73 | 1.12 | 41.2 | 110 |
| 28 | 1 | 602 | 5.61 | 2.28 | 40.6 | 107 |
| 28 | 2 | 323 | 3.04 | 1.28 | 42.1 | 106 |
| 28 | 3 | 189 | 1.65 | .67 | 40.6 | 114 |

The results are from 2-year-old trees grown but a few feet above sea level, the plants having the number "1" in each case, of course, being outside plants and located also upon the leeward side. (See Plate VII, fig. 1.)

### EXPERIMENTS WITH SEA ISLAND COTTON.

A small planting of 50 plants of this cotton was made upon the station grounds on February 10, 1910. These plants were in bloom by June 1 and the crop was picked in four pickings made on August 24, September 15, October 4, and October 31. The heaviest picking was made on October 4. The results were as follows:

*Yield of Sea Island cotton.*

| Number of plants. | Number of bolls. | Yield of seed cotton. | Number of bolls per pound. | Yield of lint. | Percentage of lint to seed cotton. | Length in 16ths inch. |
|---|---|---|---|---|---|---|
| | | *Pounds.* | | *Pounds.* | *Per cent.* | |
| 49 | 8,633 | 52.5 | 164 | 11.12 | [1] 21.2 | 26–31 |
| 1 | [1] 176 | 1.07 | ..... | .227 | 16–33 | [1] 30 |
| [2] 1,742 | ..... | 1,864 | ..... | 395 | ..... | ..... |

[1] Average. [2] One acre planted 5 by 5 feet.

One plant was taken out during the season, so that the record shows for only 49. If this is a fair example of what may be expected of Sea Island cotton there are doubtless other crops now grown in the Territory that are less profitable. The loss due to insects was estimated at about 20 per cent, which would reduce the yield by that much.

### EXPERIMENTS IN PRUNING SEA ISLAND COTTON.

The last day in December these plants were pruned back to mere stumps, some being pruned high and some low. New growth started out in all cases from near the ground, signifying that when growing Sea Island as a perennial the plants should all be low pruned. From the start the plants have grown well and fully occupied the space allowed them. It may be that when grown as a perennial it will be necessary to plant it 8 by 5 feet rather than 5 by 5 feet to allow sufficient room between the rows for ease in cultivation and picking. The plants bloomed profusely in the spring and promised an early summer crop, much of which, however, was shed, owing primarily to the attacks of the bollworm. Several of the plants also were attacked by mealy bugs so severely that it became necessary to destroy them.

FIG. 1.—CARAVONICA COTTON YIELDING 2.6 POUNDS OF LINT PER PLANT.

FIG. 2.—RUST-RESISTING SORGHUM AND AMBER SORGHUM.

No additional pruning was given the plants except that a few were pinched back just preceding squaring time, the effect of which was to cause the plants to bloom more profusely and a few days earlier than those not pinched. The first picking in 1911 was made June 15 and the percentage of infestation was very great, showing the prevalence of the bollworm at this time.

### MISCELLANEOUS EXPERIMENTS WITH SEA ISLAND COTTON.

From these plants a number of selections were made and the seed from these used in planting a new field of 1 acre upon the slope of Punchbowl. Before the first planting was finished it was washed out by heavy rains, and the second was made March 14 and 15, the hills being placed 5 by 5, as in 1910. Because of the damage to young seedlings from cutworms, a small amount of poisoned bran was spread about the hills in a small circle, which method has proved to be effective. Several seeds were planted in each hill in order to insure a stand and the poorest were weeded out at a later date. This field has shown great uniformity in growth from the start, and, although badly damaged by a windstorm on June 8, promises some good results by the end of the year. The presence of bollworm was noted in the field when in early bloom. A heavy spraying of arsenate of lead was made over a dozen rows to determine what effect, if any, this would have in checking the work of the bollworm.

Aside from the station plantings there have been a few small patches of Sea Island put in in various parts of the Territory. The only plantings of any considerable extent are at various places in Kona, Hawaii. In this district there is a Japanese cotton growers' association whose members have planted, or are planting, an area of about 500 acres. The climate and general conditions for the growth of cotton here are said to be better than at any other point, or in any other district in the Territory.

### COTTON FIBER TESTS.

The tests of Caravonica cotton fiber from pruned branches were mentioned above. It might be added here that these fibers were of smaller diameter, but of equal length with those matured upon the plant, and the breaking strength dropped from 8.99 grams to 6.24 grams. Some Mexican cotton grown at Kunia had an average strength of 8.54 grams, but the United States Department of Agriculture reports it as being less uniform than any cotton ever tested there.

Some samples of Caravonica cotton submitted from Kunia showed, from ginned cotton an average strength of 9.3 grams, while the unginned showed 11.3 grams, which at the time this was reported was the highest strength test on record.

Sea Island cotton from the same source but which was picked from some plants that had been pulled (and consequently had immature fiber) was submitted to the Clark Thread Co., which reported rather unfavorably upon it, saying it contained a large quantity of immature fiber and nep, excessive waste, and the yarn produced was too weak for thread. Former reports of Sea Island cotton were more favorable and no doubt, as stated, this failure to make good was due to the immature fiber.

When it is considered that the average strength of Big Boll American upland is about 7 grams and of long staple varieties between 4 and 5, the value of Caravonica cotton from Hawaii is readily seen, and the need for every encouragement which can be given for its production is quickly understood.

## MISCELLANEOUS CROPS.

In Hawaii the areas suitable for cultivation in the staple crops, like cane, rice, and pineapples, are fairly well defined, and the problem is to find a profitable crop for the remainder of our lands.

With this end in view, experiments were made to determine the profitableness and the limitations of cotton. Because of the use of large quantities of soy beans in the manufacture of "soy sauce" it would seem that soy beans would be a profitable crop and should be grown here rather than imported from Japan. The experiments with peanuts show that they thrive and do well here, and it may be that a peanut industry upon a large scale would be a profitable undertaking, and especially so if a number of growers in the same community could grow a sufficient area to make the erection of an oil or peanut-butter factory of some object to capitalists. One man who is experimenting with cotton has planted a quantity of peanuts in rows between the rows of cotton, insuring himself, as it were, against loss by a possible failure of the cotton. He and some others report also the growing of watermelons in like manner and at good profit.

As some interest is being shown about Honolulu in the broom industry, the station is carrying on some work with broom corn. In 1910 several rows were grown. The results calculated to acre yields show 95.4 pounds of brush from the lowest yielding row, and 501.6 from the highest. These results are rather low, as yields as high as 1,000 pounds per acre are reported from different places in the States, although, of course, average yields are not far above 500 pounds. Three plantings of corn were made again in 1911 in order to continue the test and get more complete results. This industry will probably be limited to the supplying of the local demand.

Apparently another opportunity for success upon a limited scale is the growing of sorghum and making of sorghum sirup for the

Hawaiian trade. At present the only sirup upon the Honolulu market is a corn product with "cane flavor." The sweet sorghums do well here, although attacked in the later period of their growth by rust. Quite heavy yields can be obtained, and as several ratoon crops can be grown during the year and from one seedling, 1 acre of sorghum ought to produce 1,200 to 1,500 gallons of sirup annually. Tests made upon the fourth ratoon crop this spring with only a partial extraction of the juice gave 31 per cent of juice from the stripped cane, and from this was extracted 12.1 per cent cane sugar and 2.6 per cent of invert sugar. These figures compare very favorably with those given by experiment stations in the South. This crop was grown in 90 days from the previous cutting. In view of the fact that but very little experience is necessary to learn to make the sirup; that very little outlay is required for equipment with which to make it; that no risk is run, since the leaves, tops, or grain, and the pressed canes can all be used for feeding, thus paying for the expense of raising the crop, it would seem that many Hawaiian farmers might undertake sorghum sirup making with advantage.

In connection with the above-mentioned production of forage the station has tested a number of varieties of sorghums, both saccharin and nonsaccharin. A number of these were of African origin, and from among these one was found that greatly exceeded the others in yield, while at the same time it proved to be nearly or quite rust proof. (See Plate VII, fig. 2.) The station hopes soon to distribute seed of this and thus introduce a valuable addition to our forage plants.

Soy beans, jack beans, cowpeas, velvet beans, and alfalfa were discussed in Bulletin No. 23, and require no further report here.

Another new legume, Guar, has been received from the Department of Agriculture at Washington, and its growth is very promising. Planted in rows 5 feet apart and from 2 to 6 inches in the rows one variety gave $1\frac{1}{4}$ tons to $2\frac{3}{4}$ tons per acre of air-dried forage and from 1,190 to 2,610 pounds of seed. Another variety gave yields of both seed and forage with extremes within the limits shown by this variety.

The 1910 corn trials, which included Black, Yellow Flint, Reid Yellow Dent, Boone County White, and Ensilage Pamunkey, showed the last variety and the Yellow Flint to be the better under Hawaiian conditions. In the spring of 1911 Yellow Flint and two varieties from Bolivia, Cusco and Black, were planted at the trial grounds, but were destroyed by insects. A larger planting of Yellow Creole received from New Orleans was made at a later date at the station, and at the present writing is very promising.

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